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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

USER GUIDE FOR "SUBSTRC," A FINITE ELEMENT COMPUTER PROGRAM FOR ANALYSIS OF NONLINEAR STRUCTURES

by

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STRUCTURES DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

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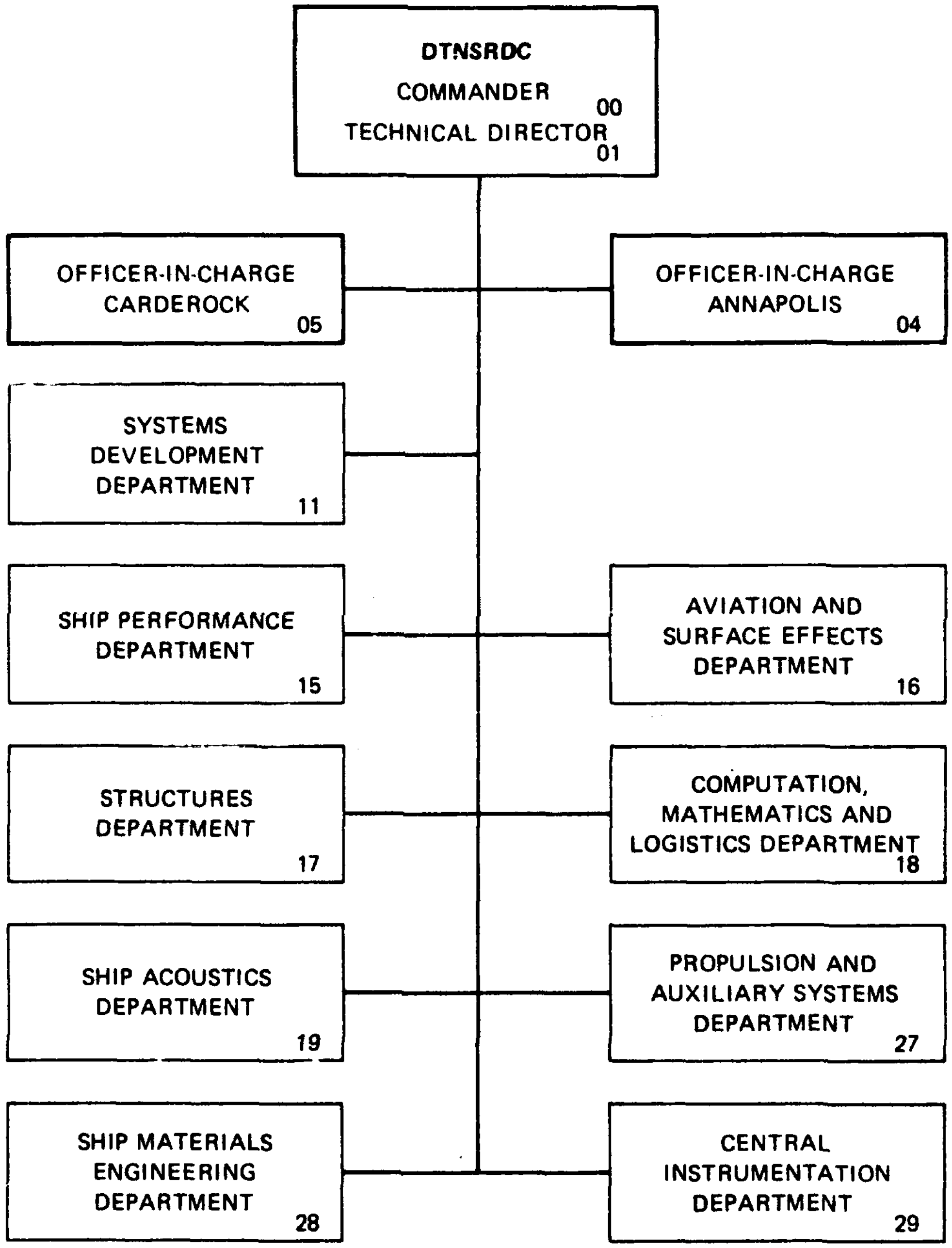

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This user guide introduces one to the use of "SUBSTRC," a finite element computer program for static analysis of nonlinear structures. It describes the input data format; and it demonstrates the use of several data generating programs. It also shows sample "SUBSTRC" output and the use of several programs to display the analysis results graphically.

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ABSTRACT

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ADMINISTRATIVE INFORMATION

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CHAPTER 1
INTRODUCTION

"SUBSTRC" is a Fortran, substructure, finite element program for nonlinear analysis of static structures. It contains a library of elements which may be used in combination to effect the analysis of a structure. Several types of tying constraints are available, allowing different element types to be tied together as well as permitting the imposition of displacement constraints.

Elastic-plastic and large displacement analysis is performed in a series of piece-wise linear increments. The formulations from both references {MARCVOLV}[1*] and {JONES73} are selectable.

The hardware configuration to run "SUBSTRC" is detailed in {POLICY}.

1.1 USER PREREQUISITES

A Finite Element Method (FEM) Computer Program for nonlinear analysis such as "SUBSTRC" cannot be approached casually. We recommend that a user be well grounded in his knowledge of the physical behavior of real structures so that "impossible" answers from a program are recognized as impossible. We recommend that a user be familiar with the FEM program he is using: this includes knowledge of the accuracy, the applicability, and the idiosyncrasies of the program. These may be gained by experience, which should be garnered from the running of "small" test cases. We

*References are enclosed in braces {and}. A complete listing of references is given in Chapter 15.

recommend that a user be familiar with the computer system he is using: this includes knowledge of the accuracy and the idiosyncrasies of both the hardware and software. Reliable descriptions of the machine accuracy can usually be obtained from the manufacturer's documentation. The system software changes quite frequently, and it is good to have a local expert to explain, in your terms, the latest changes and their effects.

1.2 HARDWARE AND SOFTWARE REQUIREMENTS

"SUBSTRC" is a large program that executes on the Control Data Corporation 6000 series computers detailed in {POLICY}. At the time of this writing, the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) CDC 6000 machines are using the "NOS/BE" operating system.

Effective FEM analysis is usually recognized as a three part sequence: pre-analysis, analysis, and post-analysis. The pre-analysis stage consists of preparing and manipulating the input data to the analysis program, and the post-analysis stage attempts to answer the question, "what did we get?" Although the pre-analysis stage could be completely done with punched cards, and the post-analysis stage could be done by visually scanning the analysis printout, there are better ways.

The fastest way to complete the pre-analysis stage is through the use of as much of the computer as possible. Interactive use of an editor (such as "NETED" {NETED}) will speed production of data card images. Other simple programs are easily written to speed input preparation. Pictures of the structure to be analyzed are no longer a luxury; they are required. These are most easily generated with interactive graphics programs such as "STAGING" {STAGINREF}. Programs for specific use with "SUBSTRC," "MARCCDC," and "TRAINS" are documented in this report. They include:

- "BEAMX" to generate coordinates for open section beam elements.
- "CM" to determine the central memory required by "SUBSTRC."
- "SHELLX" to generate coordinates for doubly curved isoparametric shell elements.
- "STON" to convert "SUBSTRC" format data to NASTRAN format data for use of NASTRAN developed software.

- "WABS" to prepare the intermediate file <NEWIN> for "SUBSTRC."

"SUBSTRC" stands by itself as the analysis component of the FEM system. However, several procedures are helpful to nonlinear analysis. These include:

- "HOLD" to preserve the results of a nonlinear analysis step.
- "RESTART" to set up the operating system for continued analysis of a nonlinear problem.

The post analysis phase also requires interactive use of the computer for effectiveness. System editors allow scanning of the output files to search for desired items quickly. Pictures, again, are not a luxury; they are required for visualization of the behavior of the mathematical model of the structure. Programs for this purpose are documented in this report. They include:

- "ADTOC" to add displacements to the original coordinates (and hence permit display of a displaced structural model).
- "DFLSIFT" to enable editing of the "SUBSTRC" displacement output file (and hence select areas of interest for display).
- "REVISE" to enable cheap revision of the restart files.
- "STRSIFT" to enable editing of the "SUBSTRC" stress output file (and hence select areas of interest for display).
- "CRUMBLE," a procedure to break a file apart for easy display.

1.3 ORGANIZATION OF THIS REPORT

It is indeed unfortunate that the information needed to pursue structural analysis on a computer cannot be presented to a new user sequentially but must proceed across a rather broad technical spectrum. Hence, we first include a list of all the elements in the "SUBSTRC" library, with the idea that the elemental modeling capabilities of the program are of immediate interest. This is followed by "a simple example," making use of several of the auxiliary programs. When you read this chapter, take some of the things that you don't understand on faith until you can read the documentation for these programs. If questions remain (or even increase!) after reading these other chapters, experiment by executing the programs in question with FEM data characterizing the problem.

Following "a simple example" alphabetically are the documents describing the software. Perhaps the best place to begin reading is Chapter 13: "WABS" (the name derives from Program W, Absolute Load). Then try Chapter 10: "SHELLX," the program which produces coordinates for triangular and quadrilateral shell elements 8 and 20 respectively. Others may be read as necessary.

While writing this book, I discovered that it would simplify things considerably if each chapter had page numbers commencing from 1. Because each chapter (save the element library) also contains the title of the chapter at the top of each page, I felt this would also be a satisfactory arrangement for the reader.

CHAPTER 2

ELEMENT LIBRARY

ELEMENT LIBRARY

THE ELEMENT LIBRARY CONTAINS ELEMENTS WHICH DATE FROM THE ORIGIN OF THE 'MARCCDC' COMPUTER PROGRAM UP THRU VERSION 'H' OF THAT CODE. ELEMENT 20, HOWEVER, WAS DEVELOPED AT THE DAVID TAYLOR NSR+DC BY JONES FOR THE ANALYSIS OF DOUBLY CURVED THIN SHELLS. THE FOLLOWING IS A BRIEF DESCRIPTION OF THE ELEMENTS IN THE 'SUBSTRC' LIBRARY. FOR MORE DETAILS, CONSULT THE APPROPRIATE REFERENCES.

1. TWO NODE AXISYMMETRIC SHELL. THIS ELEMENT IS AN AXISYMMETRIC THIN SHELL ASSEMBLED IN LOCAL COORDINATES WHICH IS THEN ROTATED INTO THE GLOBAL SYSTEM. ITS DEVELOPMENT IS DETAILED IN {KOJASTEH}, AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}. IF POSSIBLE, USE ELEMENT 15 INSTEAD.

2. AXISYMMETRIC TRIANGULAR RING. THIS ELEMENT IS AN AXISYMMETRIC SOLID BODY OF REVOLUTION. ELEMENT 10 IS A BETTER ELEMENT, AND SHOULD BE USED, IF POSSIBLE. ITS STIFFNESS IS FORMED IN LOCAL COORDINATES AND THEN ROTATED INTO THE GLOBAL SYSTEM. DEVELOPMENT DETAILS ARE GIVEN IN {CLOUGH} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

3. PLANE STRESS QUADRILATERAL. THIS IS A FOUR NODE ISOPARAMETRIC QUADRILATERAL ELEMENT. THE ELEMENT IS FORMED BY A MAPPING FROM THE X-Y PLANE TO THE G-H PLANE. THE STIFFNESS IS FORMED BY 2 X 2 GAUSSIAN INTEGRATION. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

4. VACANT.

5. BEAM COLUMN. THIS ELEMENT IS A STRAIGHT, TWO-NODE, RECTANGULAR SECTION BEAM-COLUMN ELEMENT. ELEMENT 16 IS THE BETTER ELEMENT, AND SHOULD BE USED IF POSSIBLE. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

6. TWO DIMENSIONAL PLANE STRAIN TRIANGLE. THIS ELEMENT IS THE CONSTANT STRESS (PLANE STRAIN) TRIANGLE BASED ON LINEAR DISPLACEMENT ASSUMPTIONS. IF POSSIBLE, ELEMENT 11 SHOULD BE USED, AS IT IS THE BETTER ELEMENT. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

7. THREE DIMENSIONAL BRICK. THIS IS AN EIGHT NODE

ISOPARAMETRIC ELEMENT. BETTER RESPONSE IS OBTAINED FROM ELEMENT 21, HOWEVER, WHICH SHOULD BE USED, IF POSSIBLE. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

8. DOUBLY CURVED TRIANGULAR SHELL. THIS ELEMENT IS AN ISOPARAMETRIC DOUBLY CURVED TRIANGULAR SHELL ELEMENT BASED ON THE KOITER-SANDERS SHELL THEORY. THIS ELEMENT FULFILLS ALL CONTINUITY REQUIREMENTS AND REPRESENTS RIGID BODY MOTIONS EXACTLY. DEVELOPMENT DETAILS ARE GIVEN IN {DUPUIS} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

9. THREE DIMENSIONAL TRUSS. THIS ELEMENT IS THE SIMPLE LINEAR STRAIGHT TRUSS WITH CONSTANT CROSS SECTION. THE STRAIN-DISPLACEMENT RELATIONS ARE WRITTEN FOR LARGE STRAIN, LARGE DISPLACEMENT ANALYSIS. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

10. QUADRILATERAL AXISYMMETRIC RING. THIS ELEMENT IS THE SAME FORMULATION AS ELEMENT 3, WRITTEN FOR AXISYMMETRIC GEOMETRY. IT IS AN ARBITRARY AXISYMMETRIC QUADRILATERALLY SHAPED RING SOLID. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

11. QUADRILATERAL PLANE STRAIN. THIS ELEMENT IS THE SAME FORMULATION AS ELEMENTS 3 AND 10, WRITTEN FOR PLANE STRAIN. DEVELOPMENT DETAILS ARE GIVEN IN {ZIENKIEWICZ} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

12. VACANT.

13. OPEN SECTION THIN WALL BEAM. THIS ELEMENT IS AN OPEN SECTION, CURVED, THIN WALL BEAM BEAM OF ARBITRARY SECTION. THE GEOMETRY IS INTERPOLATED CUBICALLY FROM COORDINATE AND DIRECTOR INFORMATION AT TWO NODES. DEVELOPMENT DETAILS ARE GIVEN IN {VLASOV} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

14. CLOSED SECTION BEAM IN THREE DIMENSIONS. THIS IS A SIMPLE CLOSED SECTION STRAIGHT BEAM ELEMENT WITH NO WARPING OF THE SECTION, BUT INCLUDING TWIST. THE DEFAULT CROSS SECTION IS A THIN WALLED CIRCULAR

CYLINDER: THE USER MAY SPECIFY ALTERNATVE CROSS SECTIONS THROUGH THE USE OF SUBROUTINE "CSECT." DEVELOPMENT DETAILS ARE GIVEN IN (VLASOV) AND DETAILS OF ITS USE ARE SPECIFIED IN (MARCVOL1).

15. AXISYMMETRIC ISOPARAMETRIC SHELL. THIS ELEMENT IS A TWO NODE, AXISYMMETRIC THIN SHELL ELEMENT WITH A CUBIC DISPLACEMENT ASSUMPTION BASED ON THE GLOBAL DISPLACEMENTS AND THEIR DERIVATIVES WITH RESPECT TO DISTANCE MEASURED ALONG THE SHELL. THE STRAIN DISPLACEMENT RELATIONS ARE SUITABLE FOR LARGE DISPLACEMENTS WITH SMALL STRAINS. THE STRESS STRAIN RELATIONSHIP IS INTEGRATED THROUGH THE THICKNESS BY AN 11-POINT SIMPSON'S RULE, THE FIRST AND LAST POINTS BEING ON THE SURFACE. FIVE POINT GAUSSIAN INTEGRATION IS USED ALONG THE ELEMENT. DETAILS OF ITS USE ARE SPECIFIED IN (MARCVOL1).

16. ISOPARAMETRIC CURVED 2-D BEAM. THIS ELEMENT IS A TWO NODE, ISOPARAMETRIC CURVED BEAM WITH A CUBIC DISPLACEMENT ASSUMPTION BASED ON THE GLOBAL DISPLACEMENTS AND THEIR DERIVATIVES WITH RESPECT TO DISTANCE MEASURED ALONG THE BEAM. THE STRAIN DISPLACEMENT RELATIONS ARE SUITABLE FOR LARGE DISPLACEMENTS WITH SMALL STRAINS. THE STRESS STRAIN RELATIONSHIP IS INTEGRATED THROUGH THE THICKNESS BY AN 11-POINT SIMPSON'S RULE, THE FIRST AND LAST POINTS BEING ON THE SURFACE. FIVE POINT GAUSSIAN INTEGRATION IS USED ALONG THE ELEMENT. THE DEFAULT CROSS SECTION IS A SOLID RECTANGLE. DETAILS OF ITS USE ARE SPECIFIED IN (MARCVOL1).

17. VACANT.

18. FOUR NODE ISOPARAMETRIC MEMBRANE. THIS ELEMENT IS A FOUR NODE MEMBRANE ELEMENT IN THREE SPACE, BASED ON THE FIRST ORDER ISOPARAMETRIC FORMULATION. THE ELEMENT IS SENSITIVE TO SEVERE DISTORTION: A RECTANGULAR MESH IS RECOMMENDED. DETAILS OF ITS USE ARE SPECIFIED IN (MARCVOL1).

19. GENERALIZED PLANE STRAIN QUADRILATERAL. THIS ELEMENT IS AN EXTENSION OF THE PLANE STRAIN ISOPARAMETRIC QUADRILATERAL (ELEMENT 11) GENERALIZED TO THE PLANE STRAIN CASE. THE GENERALIZED PLANE STRAIN CONDITION IS OBTAINED BY ALLOWING TWO EXTRA NODES IN EACH ELEMENT. DETAILS OF ITS USE ARE SPECIFIED IN (MARCVOL1).

20. DOUBLY CURVED QUADRILATERAL SHELL. THIS ELEMENT IS AN EXTENSION OF THE TRIANGULAR DOUBLY CURVED SHELL (ELEMENT 8). IT IS AN ISOPARAMETRIC DOUBLY CURVED QUADRILATERAL ELEMENT BASED ON THE KOITER-SANDERS SHELL THEORY. THIS ELEMENT FULFILLS ALL CONTINUITY REQUIREMENTS AND REPRESENTS RIGID BODY MOTIONS EXACTLY. DEVELOPMENT DETAILS ARE GIVEN IN {JONES77} AND DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

21. THREE DIMENSIONAL 20-NODE BRICK. THIS ELEMENT IS AN ISOPARAMETRIC THREE DIMENSIONAL BRICK. EACH EDGE FORMS A PARABOLA, SO THAT 8 NODES DEFINE THE CORNERS OF THE ELEMENT AND A FURTHER 12 NODES DEFINE THE POSITION OF THE MIDSIDE NODES. THIS ELEMENT IS A RAPIDLY CONVERGING ELEMENT FOR THREE DIMENSIONAL ANALYSIS. DETAILS OF ITS USE ARE SPECIFIED IN {MARCVOL1}.

CHAPTER 3

A SIMPLE EXAMPLE

3.1 INTRODUCTION

HERE WE PROCEED FROM THE GLEAM IN THE EYE TO THE NUMBERS COMING OUT OF 'SUBSTRC'. WE START WITH CONSIDERATION OF A (TRIVIAL) MATHEMATICAL MODEL. WE THEN GENERATE THE GRIDPOINT COORDINATES WITH TWO OF THE AUXILIARY PROGRAMS. THESE ARE MERGED INTO A FILE OF DATA INPUT TO 'WABS'. WABS ANALYZES THE DATA FOR ERRORS. WHEN ERROR-FREE DATA ARE INPUT, OR THE 'GOERRORS' FLAG IS SET, WABS PRODUCES THE <NEWIN> FILE. <NEWIN> CAN BE USED FOR PROCESSING WITH PLOTTERS (THROUGH 'STON') IF DESIRED; EVENTUALLY, IT IS PASSED AS INPUT TO 'SUBSTRC'. SUBSTRC THEN ANALYZES THE MODEL AND PRODUCES A DEFLECTION AND STRESS OUTPUT FILE.

THIS CHAPTER IS THE MOST 'DATED' OF ANY OF THE PARTS OF THIS BOOK FOR THE SIMPLE REASON THAT IT DESCRIBES WAYS TO USE PARTS OF THE CDC OPERATING SYSTEM AT DTNSRDC. OUR OPERATING SYSTEM (NOS/BE 1) IS UPGRADED AT IRREGULAR INTERVALS WITH 'IMPROVEMENTS' WHICH CHANGE CURRENT PRACTICE ONLY INCREMENTALLY. THE CUMULATIVE PROCESS IS NON-LINEAR AND SIGNIFICANT; WHAT WORKS TODAY MAY NOT (READ: PROBABLY NOT) WORK A YEAR FROM NOW. IF THIS INDEED OCCURS, CONTACT DTNSRDC CODE 1892 (COMPUTATION, MATHEMATICS AND LOGISTICS DEPARTMENT: USERS' SERVICES).

IN RE THE FIGURES ASSOCIATED WITH THIS CHAPTER: NOTE THAT INPUT AND OUTPUT FILES FROM VARIOUS PROGRAMS ARE PRESENTED. DUE TO LIMITATIONS OF THE PRINTER USED TO PRODUCE THIS DOCUMENT, ONLY THE FIRST 132 COLUMNS OF THESE FILES ARE DISPLAYED.

3.2 MATHEMATICAL MODEL

3.2.1 PHYSICAL DATA

WE CHOOSE TO MODEL A RIGHT CIRCULAR CYLINDER OF RADIUS 61.625 INCHES AND THICKNESS 0.6 INCH. THE CYLINDER IS STIFFENED WITH T-FRAMES OF DIMENSIONS SHOWN IN FIGURE 3.1. THE FRAMES ARE LOCATED AT: THE HALF

A SIMPLE EXAMPLE
MATHEMATICAL MODEL

LENGTH OF THE CYLINDER, AND AT INTERVALS OF 11.0 INCHES IN BOTH DIRECTION THEREFROM. THE CYLINDER IS MADE OF STEEL (YOUNG'S MODULUS = 3E07 PSI; POISSON'S RATIO = 0.3). TOTAL LENGTH OF THE CYLINDER IS 69.0 INCHES. THE CYLINDER IS EXPECTED TO DEFORM AXISYMMETRICALLY, AND SYMMETRICALLY ABOUT ITS HALF LENGTH.

3.2.2 MODELING CONSIDERATIONS

WE CAN MODEL HALF THE STRUCTURAL LENGTH DUE TO SYMMETRY AT THE HALF LENGTH. WE EXPECT AXISYMMETRIC BEHAVIOR, SO WE CAN MODEL 1 QUADRANT OF THE SHELL WITH A SINGLE CURVED SHELL QUADRILATERAL ELEMENT. THIS ALLOWS EASY APPLICATION OF BOUNDARY CONDITIONS. END LOADING WILL BE MODELED BY THE APPLICATION OF TWO POINT LOADS. WE ARBITRARILY CHOOSE TO MODEL THE STRUCTURE WITH 2 SUBSTRUCTURES (THERE MUST BE AT LEAST 2 SUBSTRUCTURES, AND EACH SUBSTRUCTURE MUST HAVE AT LEAST 1 INTERNAL NODE).

A SKETCH OF THE MODEL IS SHOWN IN FIGURE 3.2.

A SIMPLE EXAMPLE
INPUT TO 'WABS'

3.3 INPUT TO 'WABS'

3.3.1 SHELL ELEMENT COORDINATES

WE SHALL GENERATE THE COORDINATES FOR EACH SUBSTRUCTURE SEPARATELY.

AN EASY WAY TO GENERATE COORDINATES IS INTERACTIVELY (IT IS ASSUMED HERE THAT YOU HAVE AN ACTIVE INTERCOM ACCOUNT ON THE DTNSRDC COMPUTER SYSTEMS). PROCEED THRU THE LOGIN PROCEDURE AS OUTLINED IN (CCRM):

1. TURN THE TERMINAL ON, SETTING THE APPROPRIATE SWITCHES FOR THE TERMINAL YOU ARE USING.

2. DIAL THE COMPUTER NUMBER APPROPRIATE TO THE SPEED OF THE TELEPHONE LINE YOU ARE USING.

3. WHEN COMMUNICATIONS HAVE BEEN ESTABLISHED, THE COMPUTER WILL RESPOND WITH A GREETING WHICH APPEARS LIKE:

```
NSRDC 6X00 INTERCOM V X.Y
DATE MM/DD/YY
TIME HH.MM.SS
```

YOU THEN TYPE:

```
LOGIN,YOURID<CR>
XXXXXXXXXX<CR> ENTER ACCESS NUMBER
```

HERE WE EMPLOY '<CR>' TO INDICATE A CARRIAGE RETURN. YOU NEED TYPE ONLY THOSE LINES WHICH END WITH '<CR>'; ALL OTHERS ARE PRINTED BY THE SYSTEM.
WHEN THIS HAS BEEN CORRECTLY COMPLETED, THE INTERCOM PROMPT IS DISPLAYED:

```
COMMAND-
```

A SIMPLE EXAMPLE
INPUT TO 'WABS' - SHELL ELEMENT COORDINATES

WE ASSUME FROM THIS POINT IN THE CHAPTER, THAT YOU WILL REPLY TO THE INTERCOM SYSTEM ONLY AT THE POINTS IMMEDIATELY FOLLOWING THE INTERCOM PROMPT 'COMMAND-'. THUS, FOR EXAMPLE, IN THE COMMUNICATION:

```
COMMAND- SHELLX.<CR>
      END SHELLX
       .192 CP SECONDS EXECUTION
COMMAND-
```

THE ONLY CHARACTERS TYPED BY YOU ARE 'S', 'H', 'E', 'L', 'L', 'X', AND <CR>. ALL OTHER CHARACTERS ARE INTERCOM RESPONSES.

WE WANT TO GENERATE THE COORDINATES USING THE PROGRAM 'SHELLX' BY USING THE FAST TEXT EDITING PROGRAM 'NETED' {NETED}. SO,

```
COMMAND- ATTACH,NETED<CR>
 PFN IS NETED
 PF CYLE NO. = 001
COMMAND-
```

NOW THAT NETED IS AVAILABLE, WE CAN BEGIN.

```
COMMAND- NETED,A<CR>      (* STARTS NETED *)
--CERL-BKY-NETED X.Y
A EMPTY. INPUT.
I>
```

NOTE:

- TEXT ENCLOSED IN '(*' AND '*)' ARE BRIEF COMMENTS ON THE ACTION TYPED ON THAT LINE.
- WHEN YOU ARE EDITING, NETED PROVIDES ONE OF TWO PROMPTS: 'I>' TO INDICATE THAT AN INPUT LINE IS EXPECTED, AND 'E>' TO INDICATE THAT AN EDITING COMMAND IS EXPECTED. IN A MANNER SIMILAR TO EXECUTION OF COMMANDS IN INTERCOM, YOU ARE NOT EXPECTED TO TYPE EITHER OF THESE PROMPTS YOURSELF: THEY ARE INCLUDED TO ILLUSTRATE SYSTEM BEHAVIOR.

WE PROCEED TO ENTER EACH LINE OF INPUT FOR THE PROGRAM 'SHELLX':

```
I> CYLINDER<CR>
I> 1 0 0 61.625<CR>
I> 2 90<CR>
```

A SIMPLE EXAMPLE
INPUT TO 'WABS' - SHELL ELEMENT COORDINATES

```
I> 3 0 6.<CR>
I> 4 90<CR>
I> 5 0 17.<CR>
I> 6 90<CR>
I> .<CR>
E>
```

THE SOLITARY DOT (.) ON THE LAST LINE SIGNALS 'NETED' TO LEAVE THE INPUT MODE AND ENTER THE EDIT MODE. SINCE THE DATA APPEAR CORRECT, WE SAVE THE FILE BY:

```
E> SAVE<CR>
A WRITTEN                    (* NETED RESPONSE *)
COMMAND-
```

WE ARE NOW OUT OF NETED AND BACK INTO INTERCOM. WE WANT TO GET THE PROGRAM 'SHELLX' TO OPERATE ON THE INPUT FILE <A>. THIS IS DONE WITH:

```
COMMAND- ATTACH,SHELLX,ID=CSPR<CR>
 PFN IS SHELLX
 PF CYCLE NO.  = 000
COMMAND-
```

NOW, WE HAVE 2 PROGRAMS TO WORK WITH: 'NETED' AND 'SHELLX'. TO EXECUTE SHELLX, WE TYPE:

```
COMMAND- SHELLX<CR>
      END SHELLX
       .192 CP SECONDS EXECUTION TIME
COMMAND-
```

TO SHOW WHAT FILES EXIST AT OUR TERMINAL, WE DO:

```
COMMAND- FILES<CR>
--LOCAL FILES--
 *NETED   *SHELLX   A        B        OUTPUT
COMMAND-
```

WE NOW HAVE SEVERAL OPTIONS:

1. OUTPUT CAN BE SCANNED AT THE TERMINAL USING 'NETED' OR 'PAGE' {PAGE}, OR, IT CAN BE SIMPLY COPIED TO THE TERMINAL USING ONE OF THE SYSTEM COPY UTILITIES ('COPYE' IS PROBABLY THE FASTEST). ALTERNATIVELY, IT CAN BE ROUTED TO A PRINTER {CCRM}. WE OPT FOR THIS, AND SHOW THE OUTPUT PRODUCED BY THE XEROX PRINTER AT DTNSRDC IN FIGURE 3.3.

2. FILE <B> CAN BE ROUTED TO A PUNCH, AND CARDS MADE OF THIS FILE. HOWEVER, IT IS EASIER TO STORE <B> AS A PERMANENT FILE FOR ACCESS LATER, WHEN WE WILL MERGE IT WITH OTHER INPUT DATA. THIS IS DONE BY:

```
COMMAND- CATALOG,B,ASEXYZSUB1,ID=YOUR<CR>
 INITIAL CATALOG
 RP = 030 DAYS
 CT ID=      YOUR PFN=ASEXYZSUB1
 CT CY= 001  00000003 PRUS  $0000.01 /DAY
COMMAND-
```

NOW WE NEED THE COORDINATES FOR SUBSTRUCTURE 2. THIS MAY BE EASILY ACCOMPLISHED BY MODIFYING THE EXTANT FILE <A> SUCH THAT THE Z COORDINATES APPLY TO THE SECOND SUBSTRUCTURE. THIS CONVERSATION PROCEEDS AS FOLLOWS:

```
COMMAND- UNLOAD,B<CR>     (* REMOVE OLD <B> *)
COMMAND- NETED,A.
--CERL-BKY-NETED X.Y
EDIT.
E> L 1<CR>                (* LOCATE THE FIRST '1' *)
1 0 0 61.625              (* NETED ECHO *)
E> R 1 0 17.0 61.625<CR>  (* REPLACE THAT LINE *)
E> L 6.<CR>               (* LOCATE '6.'  *)
3 0 6.
E> C /6./28./<CR>         (* CHANGE '6.'  *)
3 0 28.
E> C /17/39/$<CR>         (* ALL '17' TO '39' *)
5 0 39.
<BOTTOM OF FILE>
E> SAVE<CR>
A WRITTEN
COMMAND-
```

NOW WE ARE BACK INTO INTERCOM READY TO RUN 'SHELLX' AGAIN WITH:

```
COMMAND- SHELLX<CR>
      END SHELLX
        .191 CP SECONDS EXECUTION TIME
COMMAND-
```

WE CATALOG THIS FILE <B> AS 'ASEXYZSUB2'.

3.3.2 BEAM ELEMENT COORDINATES

IN A SIMILAR MANNER, WE GENERATE THE INPUT FILE TO 'BEAMX' USING NETED, AND EXECUTE BEAMX FROM THE TERMINAL. WE CATALOG THE DATA FILES FROM BEAMX AS 'ASEBEAMXYZSUB1' AND 'ASEBEAMXYZSUB2'. FIGURE 3.4 SHOWS THE INPUT TO 'BEAMX' FOR SUBSTRUCTURE 1, AND FIGURE 3.5 SHOWS THE OUTPUT FOR THIS SUBSTRUCTURE. THE FILES FOR SUBSTRUCTURE 2 ARE SIMILAR, AND ARE NOT SHOWN HERE.

3.3.3 OTHER DATA

ALL OF THE OTHER DATA REQUIRED FOR 'WABS' CAN BE ASSEMBLED FROM THE TERMINAL BY MERELY TYPING IN THE REQUIRED CHARACTERS. LET'S ASSUME WE HAVE ALL THE OTHER DATA ON A FILE CALLED <OTHER>, AND WE HAVE MARKED THE PLACES WHERE THE SHELL AND BEAM COORDINATES ARE TO BE INSERTED WITH LINES AS FOLLOWS:

```
:
:
COORDINATES
20
*XYZ20SUB1
COORDINATES
13
&XYZ13SUB1
:
:
COORDINATES
20
*XYZ20SUB2
COORDINATES
13
&XYZ13SUB2
:
:
```

NOW WE NEED THE FILES OF COORDINATES WE MADE EARLIER. SO,

A SIMPLE EXAMPLE
INPUT TO 'WABS' - OTHER DATA

```
COMMAND- ATTACH,X201,ASEXYZSUB1,ID=YOUR<CR>
 PF CYCLE NO.  = 001
COMMAND- ATTACH,X202,ASEXYZSUB2,ID=YOUR<CR>
 PF CYCLE NO.  = 001
COMMAND- ATTACH,X131,ASEXYZBEAMSUB1,ID=YOUR<CR>
 PF CYCLE NO.  = 001
COMMAND- ATTACH,X132,ASEXYZBEAMSUB2,ID=YOUR<CR>
 PF CYCLE NO.  = 001
COMMAND- NETED,OTHER<CR>
--CERL-BKY NETED X.Y
EDIT.
E> F *                        (* FIND THE FIRST '*' *)
*XYZ20SUB1                    (* NETED ECHO *)
E> D                          (* DELETE THIS MARKER *)
E> M X201                     (* MERGE COORDINATES *)
X201 MERGED.
E> F                          (* FIND THE NEXT '*' *)
*XYZ20SUB2
E> D                          (* DELETE THIS MARKER *)
E> M X202                     (* MERGE AGAIN *)
X202 MERGED.
E> T                          (* GO TO TOP OF FILE *)
TOP OF FILE>
E> F &                        (* FIND THE FIRST '&' *)
&XYZ13SUB1
E> D                          (* DELETE *)
E> M X131                     (* AND MERGE *)
X131 MERGED.
E> F                          (* FIND THE NEXT '&' *)
&XYZ13SUB2
E> D                          (* ETC *)
E> M X132
X132 MERGED.
E> SAVE DATA
DATA WRITTEN.
COMMAND-
```

NOW WE HAVE A COMPLETE SET OF DATA READY FOR 'WABS' WHICH WE WANT TO PRESERVE ON A PERMANENT FILE SOMEWHERE SO WE CAN CHANGE IT LATER (IF NECESSARY), OR SO WE CAN INCLUDE IT IN A REPORT (LIKE THIS ONE), OR SO WE CAN USE IT WITHOUT HAVING TO READ THE FILE LATER FROM CARDS (SAVES TREES AND AVOIDS MALFUNCTIONING CARDREADERS), OR SO WE DON'T LOSE THE FILE IF THE COMPUTER SHOULD DIE (A RARE OCCURRENCE, BUT A POSSIBILITY).

A SIMPLE EXAMPLE
INPUT TO 'WABS' - OTHER DATA

WE CATALOG THIS FILE AS 'ASEWABSINPUT'. FIGURE 3.6 SHOWS THIS FILE.

3.4 WABS EXECUTION

WABS WAS DESIGNED TO EXECUTE IN A SMALL AMOUNT OF CENTRAL STORAGE SO THAT IT COULD BE RUN BOTH INTERACTIVELY AND BATCHLY. THE INTERACTIVE ENVIRONMENT IS MORE INTENSE, IN THAT THE RESPONSE IS FAST ENOUGH TO EXECUTE A PROGRAM WHILE THE CHARACTERISTICS OF THE THINGS YOU ARE WORKING WITH ARE FRESH IN YOUR MIND. IT IS PROBABLY IMPOSSIBLE TO SHOW THIS ENVIRONMENT ON A PRINTED PAGE, SINCE THE TIME DIMENSION IS COMPLETELY LACKING. HOWEVER, THE USE OF INTERACTIVE TOOLS TO EXAMINE FILES (SEE (PAGE) AND (NETED)) ARE SO POWERFUL THAT IT IS WORTH SPENDING SOME TIME TRYING TO GIVE THE FLAVOR OF THE OPERATION. NOTE THAT INTERACTIVE USE COMPLETELY ELIMINATES WAITING IN QUEUES FOR OTHER PEOPLES JOBS TO BE READ IN OR PRINTED. FIRST, LET US SET UP A BATCH JOB TO EXECUTE WABS, AND THEN EXAMINE THE EQUIVALENT INTERACTIVE JOB(S).

3.4.1 BATCH EXECUTION

1. THE USUAL BATCH ENVIRONMENT USES PUNCHED CARDS. HENCE, WE PROCEED TO THE KEYPUNCH (WHERE THERE MIGHT BE A QUEUE) AND PUNCH THE FOLLOWING CONTROL CARDS:

```
JOBNAME,CM61000.
CHARGE,YOUR,GOBBLYGOOK.
ATTACH,DATA,ASEWABSINPUT,ID=YOUR.
REQUEST,NEWIN,*PF.
ATTACH,WABS,ID=CSPR.
WABS.
CATALOG,NEWIN,ASENEWIN,ID=YOUR.
```

2. WE TAKE OUR CARDS TO A CARD READ STATION AND READ IN OUR CONTROL CARDS (POSSIBLE QUEUE AND POSSIBLE CARD READER DESTRUCTION OF THE INPUT DECK).

3. THE JOB IS NOW EXECUTING. HERE THERE IS THE

POSSIBILITY OF A MISPUNCHED CONTROL CARD ABORTING THE JOB, WITH THE CONSEQUENT RE-ENTERING OF THE CARD PUNCH QUEUE TO REPAIR THE FAULTY CARD, AND A RETURN TO THE CARD READ STATION TO RE-READ THE DECK.

4. WHEN THE JOB HAS EXECUTED, IT IS SENT TO THE LOCAL PRINTER. DEPENDING ON THE TRAFFIC ON THE TERMINAL, THE JOB MAY HAVE TO WAIT UNTIL OTHER JOBS HAVE COMPLETED PRINTING.

5. THE PRINTED OUTPUT IS THEN EXAMINED FOR ERRORS. ANY ERRORS MUST BE CORRECTED AND THE CYCLE BEGUN AGAIN.

IT SHOULD BE OBVIOUS THAT THERE ARE DEAD TIME SPACES IN BATCH EXECUTION OF A JOB.

3.4.2 INTERACTIVE EXECUTION

THE INTERACTIVE EXECUTION OF WABS IS USUALLY QUITE FAST. THE CONTROL CARDS SHOWN ABOVE IN THE BATCH EXECUTION ARE EXECUTED FROM A TERMINAL. ANY ERRORS IN INPUT ARE CORRECTED IMMEDIATELY; THERE IS NO WAITING FOR OTHER USERS OF THE SYSTEM TO GET OUT OF YOUR WAY. HERE WE SHOW AN EXAMPLE OF THE INTERACTIVE EXECUTION OF WABS ON THE DATA FILE JUST PREPARED:

```
COMMAND - ATTACH,WABS,ID=CSPR<CR>
 PFN IS  WABS
 PF CYCLE NO. = 016
COMMAND- ATTACH,DATA,ASEWABSINPUT,ID=YOUR<CR>
 PF CYCLE NO. = 001
COMMAND- REQUEST,NEWIN,*PF<CR>
COMMAND- WBAS,DATA<CR>   (* OOPS!  *)
 NO SUCH PROGRAM CALL NAME  -  WBAS
COMMAND- WABS,DATA<CR>
      END WARTHOG
      7.975 CP SECONDS EXECUTION TIME
COMMAND-
```

'WARTHOG' IS THE NAME OF THE MAIN PROGRAM IN WABS.

NOW THE OUTPUT FILE CAN BE EXAMINED WITH NETED OR PAGE; PERHAPS THE BEST ITEM FOR WHICH TO SEARCH IN THESE

A SIMPLE EXAMPLE
WABS EXECUTION - INTERACTIVE

FILES IS THE STRING 'ERRORS TO THIS POINT'. THIS WILL HELP TO LOCATE THE INPUT ERRORS TO EACH SUBSTRUCTURE.

THE FILES NOW AVAILABLE TO US CAN BE SEEN BY:

```
COMMAND- FILES<CR>
--LOCAL FILES--
 *NETED   *WABS     BEAM     MSDATA   OUTPUT
  NEWIN   *DATA
COMMAND-
```

THE FILES <BEAM> AND <MSDATA> ARE FILES USED INTERNALLY BY WABS; HENCE, YOU SHOULD NOT USE FILES WITH THESE NAMES YOURSELF. <BEAM> CONTAINS THE ELEMENT 13 CROSS SECTION DEFINITIONS, AND <MSDATA> IS THE MASS STORAGE RANDOM ACCESS DATA FILE.

FIGURE 3.7 IS A COPY OF THE OUTPUT FILE OF WABS, AND FIGURE 3.8 IS A COPY OF THE FILE <NEWIN>.

WHEN WE FIND THAT THERE ARE NO ERRORS REPORTED BY WABS, WE CAN BE FAIRLY CERTAIN THAT THE BOOKKEEPING FOR THE MATHEMATICAL MODEL IS CORRECT, AND WE MAY THEN CATALOG THE <NEWIN> FILE FOR LATER BATCH RUNNING OF SUBSTRC.

A SIMPLE EXAMPLE
SUBSTRC EXECUTION

3.5 SUBSTRC EXECUTION

SUBSTRC IS TOO LARGE TO EXECUTE INTERACTIVELY AT DTNSRDC BECAUSE THE OPERATING SYSTEM POLICY LIMITS THE INTERACTIVE EXECUTION OF PROGRAMS TO 61000 OCTAL WORDS. HENCE SUBSTRC, WHICH REQUIRES A MINIMUM OF 170000 OCTAL WORDS, MUST BE EXECUTED IN A BATCH MODE. HOWEVER, THE CONTROL CARDS TO EXECUTE THE PROGRAM MAY BE MADE INTERACTIVELY, AND THE CONTROL CARD IMAGES ROUTED TO THE INPUT QUEUE FROM YOUR TERMINAL. TO WIT:

```
COMMAND- NETED,CC<CR>
--CERL-BKY NETED X.Y
INPUT.
I> .<CR>                        (* INTO EDIT MODE *)
E> *<CR>                        (* TURN PROMPT OFF *)
.<CR>                           (* INTO INPUT MODE *)
YOURJOB,CM265000,T100,P2.<CR>
CHARGE,YOUR,GOBBLYGOOK.<CR>
ATTACH,SUBSTRC,ID=CSPR.<CR>
ATTACH,NEWIN,ASENEWIN,ID=YOUR.<CR>
SUBSTRC.<CR>
.<CR>
EDIT.
SAVE<CR>
CC WRITTEN.
COMMAND- CATALOG,CC,ASECC,ID=YOUR.<CR>
 INITIAL CATALOG
 RP = 030 DAYS
 CT ID=      YOUR PFN=ASECC
 CT CY= 001  00000001 PRUS  $0000.00 /DAY
COMMAND- ROUTE,CC,DC=IN,TID.<CR>
 YOURJXX.$ ENTERED INPUT QUEUE P2
COMMAND-
```

NOW WE WAIT FOR THE SYSTEM TO ALLOCATE APPROPRIATE RESOURCES TO THE JOB FOR EXECUTION.

FIGURE 3.9 IS A COPY OF THE FILE PRODUCED BY A JOB SIMILAR TO THIS.

A SIMPLE EXAMPLE
FIGURE 3.3 - 'SHELLX' OUTPUT

```
SHELLX      WEDNESDAY    08/22/79    14.07.41.

CYLINDER
1 0 0 61.625
2 90
3 0 6.
4 90
5 0 17
6 90

NODE      G            H
          X            DXDG        DXDH        Y           DYDG        DYDH        Z           DZDG        DZDH

   1    0.00000      0.00000
       61.62500      0.00000     0.00000     0.00000     1.00000     0.00000     0.00000     0.00000     1.00000

   2   96.80032      0.00000
        0.00000     -1.00000     0.00000    61.62500     0.00000     0.00000     0.00000     0.00000     1.00000

   3    0.00000      6.00000
       61.62500      0.00000     0.00000     0.00000     1.00000     0.00000     6.00000     0.00000     1.00000

   4   96.80032      6.00000
        0.00000     -1.00000     0.00000    61.62500     0.00000     0.00000     6.00000     0.00000     1.00000

   5    0.00000     17.00000
       61.62500      0.00000     0.00000     0.00000     1.00000     0.00000    17.00000     0.00000     1.00000

   6   96.80032     17.00000
        0.00000     -1.00000     0.00000    61.62500     0.00000     0.00000    17.00000     0.00000     1.00000

***     6 NODES MAPPED
```

A SIMPLE EXAMPLE
FIGURE 3.4 - 'BEAMX' INPUT

```
     2
     1    2
     7    8
57.955
6.0
0.0          90.0
     1    2
     9   10
57.955
17.0
0.0          90.0
```

A SIMPLE EXAMPLE
FIGURE 3.5 - 'BEAMX' OUTPUT

```
      GENERATION OF THE COORDINATES REQUIRED FOR    2 BEAMS (ELEMENT 13)


     BEAM NUMBER    1 IS OF TYPE    1 WITH    2 NODES

    7    8

     RADIUS =     .57955E+02, HELICAL CONSTANTS(IF REQUIRED) =    0.            0.

     Z COORDINATES
     6.00000

     ANGLES (DEGREES)
     0.00000    90.00000

     ANGLES (RADIANS)
     0.00000     1.57080

                                 C  O  O  R  D  I  N  A  T  E  S

 7  57.9550   0.0000   6.0000   0.0000   1.0000   0.0000   1.0000   0.0000   0.0000   0.0000    .0173   0.0000   0.0000
 8    .0000  57.9550   6.0000  -1.0000    .0000   0.0000    .0000   1.0000   0.0000   -.0173    .0000   0.0000  91.0355

     BEAM NUMBER    2 IS OF TYPE    1 WITH    2 NODES

    9   10

     RADIUS =     .57955E+02, HELICAL CONSTANTS(IF REQUIRED) =    0.            0.

     Z COORDINATES
    17.00000

     ANGLES (DEGREES)
     0.00000    90.00000

     ANGLES (RADIANS)
     0.00000     1.57080

                                 C  O  O  R  D  I  N  A  T  E  S

 9  57.9550   0.0000  17.0000   0.0000   1.0000   0.0000   1.0000   0.0000   0.0000   0.0000    .0173   0.0000   0.0000
10    .0000  57.9550  17.0000  -1.0000    .0000   0.0000    .0000   1.0000   0.0000   -.0173    .0000   0.0000  91.0355
```

A SIMPLE EXAMPLE
FIGURE 3.6 - 'WABS' INPUT

```
RING STIFFENED CYLINDER - 90 DEGREE SEGMENT
MODELED WITH ELEMENTS 13 AND 20 - 2 SUBSTRUCTURES
END LOAD SIMULATED BY 2 POINT LOADS
SYMMETRY PLANES AT, X-Z PLANE, Y-Z PLANE, AND Z = 39.0
LIBRARY
ELEMENTS
13 20
TYING TYPES
19 2
SUBSTRUCTURE 1
BOUNDARY CONDITIONS
0.0 1 2 1 6
0.0 2 0 3
3 5
2 4 6
0.0 2 0 3
4 6
1 3 5
0.0 1 6 8 8
CONCENTRATED LOADS
1 0 0 0 0 0 0 0.149E6
0 0
2 0 0 0 0 0 0 0.149E6
0 0
CONNECTIVITY
20
1 1 2 4 3
2 3 4 6 5
CONNECTIVITY
13
3 7 8
4 9 10
COORDINATES
20
   1   0.00000   0.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000   0.00000   0.00000   1.00000
   2  96.80032   0.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000   0.00000   0.00000   1.00000
   3   0.00000   6.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000   6.00000   0.00000   1.00000
   4  96.80032   6.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000   6.00000   0.00000   1.00000
   5   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000  17.00000   0.00000   1.00000
   6  96.80032  17.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000  17.00000   0.00000   1.00000
COORDINATES
13
   7  57.95500   0.00000   6.00000   0.00000   1.00000   0.00000   1.00000
```

A SIMPLE EXAMPLE
FIGURE 3.6 - 'WABS' INPUT (CONT'D)

```
    0.00000   0.00000   0.00000    .01725   0.00000   0.00000
     8    .00000  57.95500   6.00000  -1.00000    .00000   0.00000    .00000
    1.00000   0.00000   -.01725    .00000   0.00000  91.03550
     9  57.95500   0.00000  17.00000   0.00000   1.00000   0.00000   1.00000
    0.00000   0.00000   0.00000    .01725   0.00000   0.00000
    10    .00000  57.95500  17.00000  -1.00000    .00000   0.00000    .00000
    1.00000   0.00000   -.01725    .00000   0.00000  91.03550
DISTRIBUTED LOADS
100.0 2
1 2
EDGE NODES
5 6
GEOMETRY
0.6
1 2
0 1.0 0
3 4
PROPERTY
3E7 0.3 100000.
1 4
TIES
19
7 3 4
8 4 3
9 5 6
10 6 5
END SUBSTRUCTURE 1
SUBSTRUCTURE 2
BOUNDARY CONDITIONS
0.0 3 0 3
1 3 5
2 4 6
0.0 3 0 3
2 4 6
1 3 5
0.0 1 6 8 8
0.0 5 5 6
2 3 4 6 7 8
0.0 6 6 6
1 3 5 6 7 8
CONNECTIVITY
20
1 1 2 4 3
2 3 4 6 5
CONNECTIVITY
13
3 7 8
4 9 10
COORDINATES
```

A SIMPLE EXAMPLE
FIGURE 3.6 - 'WABS' INPUT (CONT'D)

```
20
   1   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000  17.00000   0.00000   1.00000
   2  96.80032  17.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000  17.00000   0.00000   1.00000
   3   0.00000  28.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000  28.00000   0.00000   1.00000
   4  96.80032  28.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000  28.00000   0.00000   1.00000
   5   0.00000  39.00000  61.62500   0.00000   0.00000   0.00000   1.00000
  0.00000  39.00000   0.00000   1.00000
   6  96.80032  39.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
  0.00000  39.00000   0.00000   1.00000
COORDINATES
13
   7  57.95500   0.00000  28.00000   0.00000   1.00000   0.00000   1.00000
  0.00000   0.00000   0.00000    .01725   0.00000   0.00000
   8    .00000  57.95500  28.00000  -1.00000    .00000   0.00000    .00000
  1.00000   0.00000   -.01725    .00000   0.00000  91.03550
   9  57.95500   0.00000  39.00000   0.00000   1.00000   0.00000   1.00000
  0.00000   0.00000   0.00000    .01725   0.00000   0.00000
  10    .00000  57.95500  39.00000  -1.00000    .00000   0.00000    .00000
  1.00000   0.00000   -.01725    .00000   0.00000  91.03550
DISTRIBUTED LOADS
100.0 2
1 2
EDGE NODES
1 2
GEOMETRY
0.6
1 2
0 1.0 0
3 3
0 2.
4 4
PROPERTY
3E7 0.3 100000.
1 4
TIES
19
7 3 4
8 4 3
9 5 6
10 6 5
END SUBSTRUCTURE 2
INTERSUBSTRUCTURE CONECTIVITY
READ
2
1 2 1
```

A SIMPLE EXAMPLE
FIGURE 3.6 - 'WABS' INPUT (CONT'D)

```
5 6
2 2 1
1 2
END ISC
SOLUTION DIRECTIVES
GOERRORS
END SOLUTION DIRECTIVES
ANALYSIS DIRECTIVES
ALL POINTS
LARGE DISPLACEMENT
END ANAL
BEAM CROSS SECTION DESCRIPTIONS
1 FULL SECTION
3 12 6 10
0.0. 1.33 0 -1.0 0 -1.33 0 -1.0
2.66 .58
0 1. 0 0 0 1.
1.33 0
 1.0 0 3.37 0 1. 0
3.37 .33
2 HALF-SECTION
2 6 10
0 1.33 0 -1 0 0 0 -1
1.33 .58
 1. 0 3.37 0 1.0 0
3.37 .165
END BEAM
```

A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT

```
08/17/79  09.04.39.                              W A B S   VERSION        1     LEVEL          1
                           RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

-----      RING STIFFENED CYLINDER - 90 DEGREE SEGMENT
           MODELED WITH ELEMENTS 13 AND 20 - 2 SUBSTRUCTURES
           END LOAD SIMULATED BY 2 POINT LOADS
           SYMMETRY PLANES AT: X-Z PLANE, Y-Z PLANE, AND Z = 39.0

>>>>>      LIBRARY

-----      ELEMENTS
           13 20

-----      TYING TYPES
           19 2
TYING TYPES, # RETAINED NODES
------------------------------
    1      19    2

>>>>>      SUBSTRUCTURE 1

-----      BOUNDARY CONDITIONS
MAXIMUM BOUNDARY CONDITIONS ALLOWED =    695
           0.0 1 2 1 6
           0.0 2 0 3
           3 5
           2 4 6
           0.0 2 0 3
           4 6
           1 3 5
           0.0 1 6 8 8
TOTAL BOUNDARY CONDITIONS INPUT =     30
-----------------------------------------
B O U N D A R Y   C O N D I T I O N   S U M M A R Y
------------------------------------------------------------
```

	1	2	3	4	5	6	7	8	9
1	0.	0.	0.	0.	0.	0.	FREE	0.	FREE
2	0.	0.	0.	0.	0.	0.	FREE	0.	FREE
3	FREE	0.	FREE	0.	FREE	0.	FREE	0.	FREE
4	0.	FREE	0.	FREE	0.	FREE	FREE	0.	FREE
5	FREE	0.	FREE	0.	FREE	0.	FREE	0.	FREE
6	0.	FREE	0.	FREE	0.	FREE	FREE	0.	FREE

```
-----      CONCENTRATED LOADS
CM REQUIRED:    2201 (0042318)
           1 0 0 0 0 0 0 0.149E6
```

```
A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

        0 0
        2 0 0 0 0 0 0 0.149E6
        0 0
   2 CONCENTRATED LOADS PROCESSED
------------------------------------------------------------

-----     CONNECTIVITY
CM REQUIRED:   1401 (0025710)
        20
        1 1 2 4 3
 08/17/79  09.04.59.                            W A B S   VERSION      1    LEVEL        1
                          RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

        2 3 4 6 5
   2 ELEMENTS PROCESSED
------------------------------------------------------------

-----     CONNECTIVITY
CM REQUIRED:   1401 (0025710)
        13
        3 7 8
        4 9 10
   4 ELEMENTS PROCESSED
------------------------------------------------------------

-----     COORDINATES
CM REQUIRED:   3201 (0062010)
        20
           1   0.00000   0.00000  61.62500   0.00000   0.00000   0.00000   1.00000
          0.00000   0.00000   0.00000   1.00000
           2  96.80032   0.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
          0.00000   0.00000   0.00000   1.00000
           3   0.00000   6.00000  61.62500   0.00000   0.00000   0.00000   1.00000
          0.00000   6.00000   0.00000   1.00000
           4  96.80032   6.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
          0.00000   6.00000   0.00000   1.00000
           5   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000   1.00000
          0.00000  17.00000   0.00000   1.00000
           6  96.80032  17.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
          0.00000  17.00000   0.00000   1.00000
   6 NODE POINTS PROCESSED
------------------------------------------------------------

-----     COORDINATES
CM REQUIRED:   3201 (0062010)
        13
           7  57.95580   0.00000   6.00000   0.00000   1.00000   0.00000   1.00000
          0.00000   0.00000   0.00000    .01725   0.00000   0.00000
           8    .00000  57.95580   6.00000  -1.00000    .00000   0.00000    .00000
```

A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

```
          1.00000   0.00000   -.01725    .00000   0.00000  91.03550
           9  57.95500   0.00000  17.00000   0.00000   1.00000   0.00000   1.00000
          0.00000   0.00000   0.00000    .01725   0.00000   0.00000
          10    .00000  57.95500  17.00000  -1.00000    .00000   0.00000    .00000
          1.00000   0.00000   -.01725    .00000   0.00000  91.03550
   10 NODE POINTS PROCESSED
------------------------------------------------------------

-----     DISTRIBUTED LOADS
CM REQUIRED:   1401 (0025710)
          100.0 2
          1 2
    2 DISTRIBUTED LOADS PROCESSED
------------------------------------------------------------

-----     EDGE NODES
CM REQUIRED:    201 (0003110)
          5 6
    2 EDGE NODES PROCESSED
------------------------------------------------------------

-----     GEOMETRY
CM REQUIRED:   1001 (0017510)
          0.6
          1 2
 08/17/79  09.04.39.                        W A B S   VERSION       1    LEVEL        1
                     RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

          0 1.0 0
          3 4
    2 GEOMETRIES PROCESSED
------------------------------------------------------------

-----     PROPERTY
CM REQUIRED:   1001 (0017510)
          3E7 0.3 100000.
          1 4
    1 PROPERTIES PROCESSED
------------------------------------------------------------

-----     TIES
CM REQUIRED:    801 (0014410)
          19
          7 3 4
          8 4 3
          9 5 6
          10 6 5
    4 TIES PROCESSED
------------------------------------------------------------
```

```
   A SIMPLE EXAMPLE
   FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

INTERNAL BANDWIDTH CALCULATIONS
------------------------------------------------------------

CM REQD FOR EDGE NODES:     95 (0001378)

CM REQD FOR MESH      :   1273 (0023718)

CM REQD FOR TIES      :    881 (0015618)
NODE NUMBER INDEX: USER (ROW 1) TO INTERNAL (ROW 2)
----------------------------------------------------------------------

           1    2    3    4    5    6    7    8    9   10

    1      1    2    3    4    7    8    9   10    5    6
    2      1    2    3    4    9   10    5    6    7    8

ELEMENT BANDWIDTH:       8 AT (INTERNAL) NODE:     3

ELEMENT CONNECTIONS:     6 AT (INTERNAL) NODE:     3
TIES BANDWIDTH:          8 AT (INTERNAL) NODE:     3
TIES CONNECTIONS:        8 AT (INTERNAL) NODE:     3
 08/17/79  09.04.59.                               W A B S   VERSION        1    LEVEL          1
                        RING STIFFENED CYLINDER - 90 DEGREE SEGMENT


STIFFNESS MATRIX SILHOUETTE

    0    5   10   15   20   25   30   35   40   45   50   55   60
----!----!----!----!----!----!----!----!----!----!----!----!----!-----
    1XXXX                                                            1
    2XXXX                                                            2
    3XXXXXX  XX                                                      3
    4XXXXXX  XX                                                      4
    5  XXXX                                                          5
    6  XXXX                                                          6
    7      XXXX                                                      7
    8      XXXX                                                      8
    9  XX  XXXX                                                      9
   10  XX  XXXX                                                     10
----!----!----!----!----!----!----!----!----!----!----!----!----!-----
    0    5   10   15   20   25   30   35   40   45   50   55   60
SUMMARY FOR SUBSTRUCTURE #    1
----------------------------------------------------------------------
BANDWIDTH________________     8
BOUNDARY CONDITIONS______    30
CONCENTRATED LOADS_______     2
DISTRIBUTED LOADS________     2
EDGE NODES_______________     2
ELEMENTS_________________     4
```

```
A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

GEOMETRIES_______________      2
NODES____________________     10
PROPERTIES_______________      1
TIES_____________________      4
ERRORS TO THIS POINT_____      0

-----     END SUBSTRUCTURE 1

>>>>>     SUBSTRUCTURE 2

-----     BOUNDARY CONDITIONS
MAXIMUM BOUNDARY CONDITIONS ALLOWED =   695
          0.0 3 0 3
          1 3 5
          2 4 6
          0.0 3 0 3
          2 4 6
          1 3 5
          0.0 1 6 8 8
          0.0 5 5 6
          2 3 4 6 7 8
          0.0 6 6 6
          1 3 5 6 7 8
TOTAL BOUNDARY CONDITIONS INPUT =    20
------------------------------------------------------------------------
B O U N D A R Y   C O N D I T I O N   S U M M A R Y
------------------------------------------------------------------------

          1         2         3         4         5         6         7         8         9

 08/17/79  09.04.59.                              W A B S   VERSION        1    LEVEL         1
                        RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

    1     FREE     0.        FREE     0.        FREE     0.        FREE     0.        FREE
    2    0.        FREE     0.        FREE     0.        FREE     FREE     0.        FREE
    3     FREE     0.        FREE     0.        FREE     0.        FREE     0.        FREE
    4    0.        FREE     0.        FREE     0.        FREE     FREE     0.        FREE
    5     FREE     0.       0.        0.        FREE     0.       0.        0.        FREE
    6    0.        FREE     0.        FREE     0.       0.       0.        0.        FREE

-----     CONNECTIVITY
CM REQUIRED:   1401 (0025710)
          20
          1 1 2 4 3
          2 3 4 6 5
    2 ELEMENTS PROCESSED
------------------------------------------------------------------------

-----     CONNECTIVITY
```

A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

```
CM REQUIRED:   1401 (0025718)
         13
         3 7 8
         4 9 10
    4 ELEMENTS PROCESSED
----------------------------------------------------------------------

-----    COORDINATES
CM REQUIRED:   3201 (0062018)
         20
            1   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000   1.00000
         0.00000  17.00000   0.00000   1.00000
            2  96.80032  17.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
         0.00000  17.00000   0.00000   1.00000
            3   0.00000  28.00000  61.62500   0.00000   0.00000   0.00000   1.00000
         0.00000  28.00000   0.00000   1.00000
            4  96.80032  28.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
         0.00000  28.00000   0.00000   1.00000
            5   0.00000  39.00000  61.62500   0.00000   0.00000   0.00000   1.00000
         0.00000  39.00000   0.00000   1.00000
            6  96.80032  39.00000   -.00000  -1.00000   0.00000  61.62500   -.00000
         0.00000  39.00000   0.00000   1.00000
    6 NODE POINTS PROCESSED
----------------------------------------------------------------------

-----    COORDINATES
CM REQUIRED:   3201 (0062018)
         13
            7  57.95500   0.00000  28.00000   0.00000   1.00000   0.00000   1.00000
         0.00000   0.00000   0.00000    .01725   0.00000   0.00000
            8    .00000  57.95500  28.00000  -1.00000    .00000   0.00000    .00000
         1.00000   0.00000   -.01725    .00000   0.00000  91.03550
            9  57.95500   0.00000  39.00000   0.00000   1.00000   0.00000   1.00000
         0.00000   0.00000   0.00000    .01725   0.00000   0.00000
           10    .00000  57.95500  39.00000  -1.00000    .00000   0.00000    .00000
         1.00000   0.00000   -.01725    .00000   0.00000  91.03550
   10 NODE POINTS PROCESSED
----------------------------------------------------------------------

-----    DISTRIBUTED LOADS
CM REQUIRED:   1401 (0025718)
         100.0 2
         1 2
    2 DISTRIBUTED LOADS PROCESSED
----------------------------------------------------------------------
 08/17/79  09.04.59.                          W A B S   VERSION     1    LEVEL        1
                      RING STIFFENED CYLINDER - 90 DEGREE SEGMENT
```

```
A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

-----     EDGE NODES
CM REQUIRED:    201 (000311B)
          1 2
    2 EDGE NODES PROCESSED
----------------------------------------------------------------------

-----     GEOMETRY
CM REQUIRED:   1001 (001751B)
          0.6
          1 2
          0 1.0 0
          3 3
          0 2.
          4 4
    3 GEOMETRIES PROCESSED
----------------------------------------------------------------------

-----     PROPERTY
CM REQUIRED:   1001 (001751B)
          3E7 0.3 100000.
          1 4
    1 PROPERTIES PROCESSED
----------------------------------------------------------------------

-----     TIES
CM REQUIRED:    801 (001441B)
          19
          7 3 4
          8 4 3
          9 5 6
          10 6 5
    4 TIES PROCESSED
----------------------------------------------------------------------
INTERNAL BANDWIDTH CALCULATIONS
----------------------------------------------------------------------

CM REQD FOR EDGE NODES:     95 (000137B)

CM REQD FOR MESH      :   1273 (002371B)

CM REQD FOR TIES      :    881 (001561B)
NODE NUMBER INDEX: USER (ROW 1) TO INTERNAL (ROW 2)
----------------------------------------------------------------------

          1    2    3    4    5    6    7    8    9   10

   1      3    4    5    6    7    8    9   10    1    2
   2      9   10    1    2    3    4    5    6    7    8
```

```
   A SIMPLE EXAMPLE
   FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)


ELEMENT BANDWIDTH:       10 AT (INTERNAL) NODE:     1

ELEMENT CONNECTIONS:      6 AT (INTERNAL) NODE:     1
TIES BANDWIDTH:          10 AT (INTERNAL) NODE:     1
TIES CONNECTIONS:         8 AT (INTERNAL) NODE:     1
 08/17/79  09.04.59.                              W A B S   VERSION        1    LEVEL          1
                       RING STIFFENED CYLINDER - 90 DEGREE SEGMENT


STIFFNESS MATRIX SILHOUETTE

    0    5   10   15   20   25   30   35   40   45   50   55   60
----!----!----!----!----!----!----!----!----!----!----!----!----!-----
    1XXXXXX  XX                                                      1
    2XXXXXX  XX                                                      2
    3XXXX  XX                                                        3
    4XXXX  XX                                                        4
    5XX  XX                                                          5
    6XX  XX                                                          6
    7  XX  XX                                                        7
    8  XX  XX                                                        8
    9XX      XX                                                      9
   10XX      XX                                                     10
----!----!----!----!----!----!----!----!----!----!----!----!----!-----
    0    5   10   15   20   25   30   35   40   45   50   55   60
SUMMARY FOR SUBSTRUCTURE #    2
----------------------------------------------------------------------
BANDWIDTH________________   10
BOUNDARY CONDITIONS______   20
DISTRIBUTED LOADS________    2
EDGE NODES_______________    2
ELEMENTS_________________    4
GEOMETRIES_______________    3
NODES____________________   10
PROPERTIES_______________    1
TIES_____________________    4
ERRORS TO THIS POINT_____    0

-----     END SUBSTRUCTURE 2

>>>>>     INTERSUBSTRUCTURE CONECTIVITY

-----     READ                                                                          145
          2

CM REQUIRED:    6405 (014405B)
          1 2 1
          5 6
          2 2 1
```

A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

```
         1 2
INTERSUBSTRUCTURE CONNECTIONS
------------------------------------------------------------------------------------------------------------------------------

          1    2

    1     5    1
    2     6    2

CM REQUIRED:     65 (8001818)
EDGE STIFFNESS BANDWIDTH =    2 IN SUBSTRUCTURE     1

-----    END ISC

>>>>>    SOLUTION DIRECTIVES
 08/17/79  09.04.59.                         W A B S   VERSION       1    LEVEL         1                  PAGE      8
                       RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

-----    GOERRORS

-----    END SOLUTION DIRECTIVES

>>>>>    ANALYSIS DIRECTIVES

-----    ALL POINTS

-----    LARGE DISPLACEMENT

-----    END ANAL

>>>>>    BEAM CROSS SECTION DESCRIPTIONS
         1 FULL SECTION
         3 12 6 10
PROCESSING     3 BRANCHES
------------------------------------------------------------------------------------------------------------------------------
         0.0, 1.33 0 -1.0 0 -1.33 0 -1.0
         2.66 .58
         0 1. 0 0 0 1.
         1.33 0
          1.C 0 3.37 0 1. 0
         3.37 .33
         2 HALF-SECTION
         2 6 10
PROCESSING     2 BRANCHES
------------------------------------------------------------------------------------------------------------------------------
         0 1.33 0 -1 0 0 0 -1
         1.33 .58
          1. C 3.37 0 1.0 0
```

```
A SIMPLE EXAMPLE
FIGURE 3.7 - 'WABS' OUTPUT (CONT'D)

      3.37 .165
 2 BEAM SECTIONS PROCESSED
------------------------------------------------------------------------------------------------------------------------

-----     END BEAM
08/17/79  09.04.59.                            W A B S   VERSION        1    LEVEL          1
                        RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

C E N T R A L   M E M O R Y   R E Q U I R E M E N T S

                                  TAPE12     TAPE14
                  MXRD     SPACE  RNDF12     RANDF2

TARGETS:                   35000     450        450

COMPUTED:
                    10     21028      64         64         64

...CM AVAILABLE
```

A SIMPLE EXAMPLE
FIGURE 3.8 - THE FILE <NEWIN>

```
RING STIFFENED CYLINDER - 90 DEGREE SEGMENT
     35000     0  450  450
    2   13    20
1 FULL SECTION
    3   12     6   10
    0.00000   1.33000   0.00000  -1.00000   0.00000  -1.33000   0.00000  -1.00000
    2.66000    .58000    .58000
    0.00000  -1.33000   0.00000   1.00000   0.00000   0.00000   0.00000   1.00000
    1.33000   0.00000   0.00000
    0.00000   0.00000   1.00000   0.00000   3.37000   0.00000   1.00000   0.00000
    3.37000    .33000    .33000
2 HALF-SECTION
    2    6    10
    0.00000   1.33000   0.00000  -1.00000   0.00000   0.00000   0.00000  -1.00000
    1.33000    .58000    .58000
    0.00000   0.00000   1.00000   0.00000   3.37000   0.00000   1.00000   0.00000
    3.37000    .16500    .16500
LAST
    1    0    0    1
    2   10   10   10    0    0    4    1    3    2
    0    0    0    1    0    0    0    0    0    0
    4   10   30    1    0    0
    2    8    2   10    2    2    1    2    1    0
    0    0    0    0    1    1    0
    2    1    1
SUBSTRUCTURE     1
    4   10   30    8    0    4
BOUNDARY CONDITIONS
   30
    1    1    1    1 0.
    1    1    2    2 0.
    1    1    3    3 0.
    1    1    4    4 0.
    1    1    5    5 0.
    1    1    6    6 0.
    1    1    8    8 0.
    2    2    1    1 0.
    2    2    2    2 0.
    2    2    3    3 0.
    2    2    4    4 0.
    2    2    5    5 0.
    2    2    6    6 0.
    2    2    8    8 0.
    3    3    2    2 0.
    3    3    4    4 0.
    3    3    6    6 0.
    3    3    8    8 0.
    4    4    1    1 0.
    4    4    3    3 0.
```

A SIMPLE EXAMPLE
FIGURE 3.8 - THE FILE <NEWIN> (CONT'D)

```
    4   10   28   10    0    4
BOUNDARY CONDITIONS
   28
    1    1    2    2 0.
    1    1    4    4 0.
    1    1    6    6 0.
    1    1    8    8 0.
    2    2    1    1 0.
    2    2    3    3 0.
    2    2    5    5 0.
    2    2    8    8 0.
    3    3    2    2 0.
    3    3    4    4 0.
    3    3    6    6 0.
    3    3    8    8 0.
    4    4    1    1 0.
    4    4    3    3 0.
    4    4    5    5 0.
    4    4    8    8 0.
    5    5    2    2 0.
    5    5    3    3 0.
    5    5    4    4 0.
    5    5    6    6 0.
    5    5    7    7 0.
    5    5    8    8 0.
    6    6    1    1 0.
    6    6    3    3 0.
    6    6    5    5 0.
    6    6    6    6 0.
    6    6    7    7 0.
    6    6    8    8 0.
CONNECTIVITY
    4
    1   20    1    2    4    3
    2   20    3    4    6    5
    3   13    7    8
    4   13    9   10
COORDINATES
   13   10
    1   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000
   1.00000   0.00000  17.00000   0.00000   1.00000   0.00000
   0.00000
    2  96.80032  17.00000   0.00000  -1.00000   0.00000  61.62500
   0.00000   0.00000  17.00000   0.00000   1.00000   0.00000
   0.00000
    3   0.00000  28.00000  61.62500   0.00000   0.00000   0.00000
   1.00000   0.00000  28.00000   0.00000   1.00000   0.00000
   0.00000
    4  96.80032  28.00000   0.00000  -1.00000   0.00000  61.62500
```

A SIMPLE EXAMPLE
FIGURE 3.8 - THE FILE <NEWIN> (CONT'D)

```
    0.00000    0.00000   28.00000    0.00000    1.00000    0.00000
    0.00000
     5    0.00000   39.00000   61.62500    0.00000    0.00000    0.00000
    1.00000    0.00000   39.00000    0.00000    1.00000    0.00000
    0.00000
     6   96.80032   39.00000    0.00000   -1.00000    0.00000   61.62500
    0.00000    0.00000   39.00000    0.00000    1.00000    0.00000
    0.00000
     7   57.95500    0.00000   28.00000    0.00000    1.00000    0.00000
    1.00000    0.00000    0.00000    0.00000     .01725    0.00000
    0.00000
     8    0.00000   57.95500   28.00000   -1.00000    0.00000    0.00000
    0.00000    1.00000    0.00000    -.01725    0.00000    0.00000
   91.03550
     9   57.95500    0.00000   39.00000    0.00000    1.00000    0.00000
    1.00000    0.00000    0.00000    0.00000     .01725    0.00000
    0.00000
    10    0.00000   57.95500   39.00000   -1.00000    0.00000    0.00000
    0.00000    1.00000    0.00000    -.01725    0.00000    0.00000
   91.03550
TRACTIONS
     0     2
     1     2
     1
   .10000000E+03
     1     2
     2
   .10000000E+03
GEOMETRY
     4
     .60000    0.00000    0.00000
     1     1
     .60000    0.00000    0.00000
     2     2
    0.00000    1.00000    0.00000
     3     3
    0.00000    2.00000    0.00000
     4     4
PROPERTY
     4
  .3000E+08     .30000    0.00000    0.00000    0.00000 .1000E+06
     1     1
  .3000E+08     .30000    0.00000    0.00000    0.00000 .1000E+06
     2     2
  .3000E+08     .30000    0.00000    0.00000    0.00000 .1000E+06
     3     3
  .3000E+08     .30000    0.00000    0.00000    0.00000 .1000E+06
     4     4
TYING
```

A SIMPLE EXAMPLE
FIGURE 3.8 - THE FILE <NEWIN> (CONT'D)

```
   19     2
   19     7
    3     4
   19     8
    4     3
   19     9
    5     6
   19    10
    6     5
END OPTION
    2     1     2
    2     2
    2     1
    5     6
    2     1
    1     2
CONTINUE
CONTINUE
   -1
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT

NSRDC SUBSTRUCTURE PROGRAM 08/17/79 17.33.52.

RING STIFFENED CYLINDER - 90 DEGREE SEGMENT

MAXALL	IDIM	IRO1	IRO2	INEW
35000	0	450	450	0

NELTYP	ELEM I.D.	NOS
2	13	20

1 FULL SEC

NO.OF BRANCHES 3 INTERVALS PER BRANCH 12 6 10

BRANCH DEFINITION

BRANCH	X1	Y1	X1P	Y1P	X2	Y2	X2P	Y2P	PL	T1	T2
1	0.000	1.330	0.000	-1.000	0.000	-1.330	0.000	-1.000	2.660	.580	.580
2	0.000	-1.330	0.000	1.000	0.000	0.000	0.000	1.000	1.330	0.000	0.000
3	0.000	0.000	1.000	0.000	3.370	0.000	1.000	0.000	3.370	.330	.330

2 HALF-SEC

NO.OF BRANCHES 2 INTERVALS PER BRANCH 6 10

BRANCH DEFINITION

BRANCH	X1	Y1	X1P	Y1P	X2	Y2	X2P	Y2P	PL	T1	T2
1	0.000	1.330	0.000	-1.000	0.000	0.000	0.000	-1.000	1.330	.580	.580
2	0.000	0.000	1.000	0.000	3.370	0.000	1.000	0.000	3.370	.165	.165

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

LAST

1 FULL SEC

SECTION 1

POINT NO.	COORDINATES IN SECTION,		THICKNESS,	WEIGHT,	WARPING FTN.
1	0.00000	1.33300	.58000	.04286	0.00000
2	0.00000	1.10833	.58000	.17142	0.00000
3	0.00000	.88667	.58000	.08571	0.00000
4	0.00000	.66500	.58000	.17142	0.00000
5	0.00000	.44333	.58000	.08571	0.00000
6	0.00000	.22167	.58000	.17142	0.00000
7	0.00000	-.00000	.91000	.12278	0.00000
8	0.00000	-.22167	.58000	.17142	0.00000
9	0.00000	-.44333	.58000	.08571	0.00000
10	0.00000	-.66500	.58000	.17142	0.00000
11	0.00000	-.88667	.58000	.08571	0.00000
12	0.00000	-1.10833	.58000	.17142	0.00000
13	0.00000	-1.33000	.58000	.04286	0.00000
14	.33700	0.00000	.33000	.14828	0.00000
15	.67400	0.00000	.33000	.07414	0.00000
16	1.01100	0.00000	.33000	.14828	0.00000
17	1.34800	0.00000	.33000	.07414	0.00000
18	1.68500	0.00000	.33000	.14828	0.00000
19	2.02200	0.00000	.33000	.07414	0.00000
20	2.35900	0.00000	.33000	.14828	0.00000
21	2.69600	0.00000	.33000	.07414	0.00000
22	3.03300	0.00000	.33000	.14828	0.00000
23	3.37000	0.00000	.33000	.03707	0.00000

2 HALF-SEC

SECTION 2

POINT NO.	COORDINATES IN SECTION,		THICKNESS,	WEIGHT,	WARPING FTN.
1	0.00000	1.33000	.58000	.04286	0.00000

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

2	0.00000	1.10833	.58000	.17142	0.00000
3	0.00000	.88667	.58000	.08571	0.00000
4	0.00000	.66500	.58000	.17142	0.00000
5	0.00000	.44333	.58000	.08571	0.00000
6	0.00000	.22167	.58000	.17142	0.00000
7	0.00000	0.00000	.37250	.06139	0.00000
8	.33700	0.00000	.16500	.07414	0.00000
9	.67400	0.00000	.16500	.03707	0.00000
10	1.01100	0.00000	.16500	.07414	0.00000
11	1.34800	0.00000	.16500	.03707	0.00000
12	1.68500	0.00000	.16500	.07414	0.00000
13	2.02200	0.00000	.16500	.03707	0.00000
14	2.35900	0.00000	.16500	.07414	0.00000
15	2.69600	0.00000	.16500	.03707	0.00000
16	3.03300	0.00000	.16500	.07414	0.00000
17	3.37000	0.00000	.16500	.01854	0.00000

* * * * * * * * * * *

KEY TO STRAIN, STRESS AND DISPLACEMENT OUTPUT

ELEMENT TYPE 13

THIN-WALLED BEAM WITH OPEN CROSS-SECTION

STRAIN AND STRESS ARE UNIAXIAL

DISPLACEMENTS 1=U.2=U.S.3=V.4=V.S.5=W.6=W.S.7=TETA.8=TETA.S

U,V,W=CARTESIAN DISPLACEMENTS,TETA=ANGLE OF TWIST

.S DENOTES DERIVATIVE WITH RESPECT TO LENGTH ON BEAM AXIS

ELEMENT TYPE 20
4 NODE QUADRILATERAL SHELL
STRAINS - STRETCH AND BEND WITH RESPECT TO GAUSSIAN SURFACE COORDS.

STRESSES- 1=GG, 2=HH, 3=GH, WHERE G AND H ARE COORDS. IN SURFACE REPEATED AT EACH FIBER THROUGH THICKNESS

DISPLACEMENTS, 1=U, 2=DU/DG, 3=DU/DH, 4=V, ETC.

* * * * * * * * * * *

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

PROCEDURE CONTROL CARDS
  LARGED   RESID   KINHRD   LODCOR
     1       0       0        1
 ICRT  MAXNP  MAXBW  MXRD  IELAS  IPRBLD  ITIEM  ISTYPM  LONGTM   NUMDIS
    2     10     10    10      0       0      4       1       3        2
 MESHR  IPLOT  IRSTRT  IELSTO  IDEV  IFULL  IOFF  IBUILD  ICUR DEROACH
     5      0       0       1     0      0     0       0     0       0


MAXIMUM DIMENSION CARDS

 NUMEL, NUMNP, NUMBC, NSTRES,NPRMAX,NBCTMX,MPTPMX
     4     10     30      1      0      0      3
MPRMAX NPIMAX NPBMAX NUMMAX NSTCON NTPBO NNIMIN
     2      8      2     10      2     2      1       2       1       0
SKIPSOL RESTART STIFTAP ELTAP IPROV ISUBPR
   0       0       0      0     1     1     0

* * * * * * * * * *

GENERATED DATA
     9     33      4      6     13

MXRD:     10

  227   227   228   229   230  2076   231   232   233  2076  3372  7260  8604  8640  9720  9936 11232 11313 11494 19650
19731 19812 19893 19893 19893 19983 20064   234   531   828     1    19    37    67  2075    97    31    35 201+5    36
  227   187 11394     0  2076   107  8604 20307 20955   171   179 21963

MINIMUM MASS STORAGE FILE INDEX LENGTHS:
TAPE12, COMMON BLOCK /RNDF12/...   64
TAPE14,              /RANDF2/...   64
TAPE15,              /IRDF15/...   64


MINIMUM LENGTH OF COMMON BLOCK /SPACE/ :     23141 (055145B)


CPU IN:      1.008, CPU OUT:      1.299, CPU TOTAL:       .291 OMARC

   2 SUBSTRUCTURES
  1    1
```

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

 DATA FOR SUBSTRUCTURE NO   1


NUMEL,NUMNP,NUMBC,MAXBW,NBCTRA,ITIE,IENR1(ISST)
   4   10   30    8    0    4    0

MPRMAX
     2
    1


GENERATED ELEM DATA

* * * * * * * * * * *
NELTYP, MTYPE,MNOPTE,ICROUT,TSMALL,  IEXP,   IRHS
     2      0     4      1      0      0      0

TYPE IS   1  WITH 2  NODES AND23  STRAINS AND 1  DIRECT 0  SHEAR STRESS, ISHELL= 1
ROW CORRESPONDENCE FOR EXPANDED MATRIX
232 1 1 1 5 5 3 5 4 0 C 0 0 0 0 222 2 0 1 5 5 3 5 4 0 C 0 0 211 1 0 1 5
INTEL  INTIN  ISNTE  INTPRE
   5     5     3     5
ROWS WITH SECOND ORDER DISPLACEMENT TERMS
   6     0     C     0     0     0

TYPE IS   2  WITH 4  NODES AND33  STRAINS AND 2  DIRECT 1  SHEAR STRESS, ISHELL= 1
ROW CORRESPONDENCE FOR EXPANDED MATRIX
0 6 3 3 0272714 9 6 6 6111111 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
INTEL  INTIN  ISNTE  INTPRE
   9     9     5     9
ROWS WITH SECOND ORDER DISPLACEMENT TERMS
   6     6    11     0     0     0

ICURV  ICTRNS  IBXA  IDBXA  IDEV NBCTRA NUPTRA  IUPDAT MESHR LODCOR
     0      1      0      0      0      0      0      0      5      2

* * * * * * * * * * *

BOUNDARY C

NO.OF CARDS FOR B.C.=   30

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     1     1  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     2     2  0.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     3     3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     4     4  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     5     5  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     6     6  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   1     1     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     1     1  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     2     2  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     3     3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     4     4  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     5     5  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     6     6  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   2     2     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   3     3     2     2  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   3     3     4     4  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   3     3     6     6  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   3     3     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
    4     4     1     1   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     3     3   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     5     5   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     8     8   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     2     2   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     4     4   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     6     6   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     8     8   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    6     6     1     1   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    6     6     3     3   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    6     6     5     5   0.

 FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    6     6     8     8   0.

    30  DEG. OF FREEDOM FIXED
 NO  ND NO  DEG FIX DISP,NO   ND.NO  DEG  FIXED DISP
    1     1     1 0.            2     1     2 0.
    3     1     3 0.            4     1     4 0.
    5     1     5 0.            6     1     6 0.
    7     1     8 0.            8     2     1 0.
    9     2     2 0.           10     2     3 0.
   11     2     4 0.           12     2     5 0.
   13     2     6 0.           14     2     8 0.
   15     3     2 0.           16     3     4 0.
   17     3     6 0.           18     3     8 0.
   19     4     1 0.           20     4     3 0.
   21     4     5 0.           22     4     8 0.
   23     5     2 0.           24     5     4 0.
```

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)


25      5      6 0.              26      5      8 0.
27      6      1 0.              28      6      3 0.
29      6      5 0.              30      6      8 0.

TRACTIONS

  2  NODAL LOADS LISTED BELOW
1 0.          0.          0.          0.          0.          0.
  .149E+06 0.          0.
2 0.          0.          0.          0.          0.          0.
  .149E+06 0.          0.

CONNECTIVI

NUMEL1,MESHR1
    4      5

NUMEL  TYPE  NODE NUMBERS ANTICLOCKWISE
  1    20    1     2     4     3
  2    20    3     4     6     5
  3    13    7     8     0     0
  4    13    9    10     0     0

CONTROL

  MINC,NINST2,NINST1, NCYCM,  IRHS,IUPDAT,NUPTRA,  IOPT
    1      1      7      3      0      0      0      0      1      0
FRCTOL  FACINIT  FLAMB  TOLER  XFAC
 2.00000    .10000    .00010    .00010   1.85000

COORDINATE

NCRD1=    13  NUMNP1=    10  MESHR1=    5

NPNUM  COORDS
  1    0.00000   0.00000  61.62500   0.00000   0.00000   0.00000
 1.00000   0.00000   0.00000   0.00000   1.00000   0.00000
 0.00000
  2  96.80032   0.00000   0.00000  -1.00000   0.00000  61.62500
 0.00000   0.00000   0.00000   0.00000   1.00000   0.00000
 0.00000
  3    0.00000   5.00000  61.62500   0.00000   0.00000   0.00000
 1.00000   0.00000   6.00000   0.00000   1.00000   0.00000
 0.00000
  4  96.80032   5.00000   0.00000  -1.00000   0.00000  61.62500
 0.00000   0.00000   6.00000   0.00000   1.00000   0.00000
 0.00000
  5    0.00000  17.00000  61.62500   0.00000   0.00000   0.00000
 1.00000   0.00000  17.00000   0.00000   1.00000   0.00000
```

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)


0.00000
 6  96.80032  17.00000   0.00000  -1.00000   0.00000  61.62500
0.00000   0.00000  17.00000   0.00000   1.00000   0.00000
0.00000
 7  57.95500   0.00000   6.00000   0.00000   1.00000   0.00000
1.00000   0.00000   0.00000   0.00000    .01725   0.00000
0.00000
 8   0.00000  57.95500   6.00000  -1.00000   0.00000   0.00000
0.00000   1.00000   0.00000   -.01725   0.00000   0.00000
91.03550
 9  57.95500   0.00000  17.00000   0.00000   1.00000   0.00000
1.00000   0.00000   0.00000   0.00000    .01725   0.00000
0.00000
10   0.00000  57.95500  17.00000  -1.00000   0.00000   0.00000
0.00000   1.00000   0.00000   -.01725   0.00000   0.00000
91.03550

TRACTIONS

   1  ELEMS WITH DISTRIB. LOAD OF MAGNITUDE   .1000000E+03  AND TYPE   2
    1

   1  ELEMS WITH DISTRIB. LOAD OF MAGNITUDE   .1000000E+03  AND TYPE   2
    2

   0  NODAL LOADS LISTED BELOW

GEOMETRY

NO OF DISTINCT ELEM. GEOMS =     4
 EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
 .600E+00  0.         0.          0.        0.
ELEM GEOM FOR ELEM     1  TO     1
 EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
 .600E+00  0.         0.          0.        0.
ELEM GEOM FOR ELEM     2  TO     2
 EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
0.          .100E+01  0.          0.        0.
ELEM GEOM FOR ELEM     3  TO     3
 EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
0.          .100E+01  0.          0.        0.
ELEM GEOM FOR ELEM     4  TO     4

PROPERTY
NO OF DISTINCT ELEM PROP=    4
YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP., YIELP2
 .300E+08   .300E+00  0.        0.        0.          .100E+06  0.
ELEM PROPS FROM ELEM     1  TO     1
YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP., YIELP2
```

```
 .300E+08  .300E+00 0.        0.        0.        .100E+06 0.
ELEM PROPS FROM ELEM    2  TO    2
YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
 .300E+08  .300E+00 0.        0.        0.        .100E+06 0.
ELEM PROPS FROM ELEM    3  TO    3
YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
 .300E+08  .300E+00 0.        0.        0.        .100E+06 0.
ELEM PROPS FROM ELEM    4  TO    4

TYING

NO. TIED NODES    4

TIE TYPE,NO.RETAINED NODES
  19    2

TIE NO  1  TYPE 19  TIED NODE  7  NO.RET.NODES  2
RETAINED NODES    3    4

TIE NO  2  TYPE 19  TIED NODE  8  NO.RET.NODES  2
RETAINED NODES    4    3

TIE NO  3  TYPE 19  TIED NODE  9  NO.RET.NODES  2
RETAINED NODES    5    6

TIE NO  4  TYPE 19  TIED NODE 10  NO.RET.NODES  2
RETAINED NODES    6    5

END OPTION

CPU IN:      1.352, CPU OUT:      2.591, CPU TOTAL:      1.239 OAREAD


   2 BOUNDARY NODES    8 INTERIOR NODES


LIST OF BOUNDARY NODES
   5    6
/RANDF2/ MUST BE .GE.         64


CPU IN:      3.043, CPU OUT:      3.320, CPU TOTAL:       .277 OPRESS



CPU IN:      3.334, CPU OUT:      8.844, CPU TOTAL:      5.510 OASEMB
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
NEW ITIX

    1     5     3     4
    2     6     4     3
    3     7     9    10
    4     8    10     9

TYING BEAM NODE   5  TO SHELL NODE   3
OFFSET:    -3.67000

TYING BEAM NODE   6  TO SHELL NODE   4
OFFSET:    -3.67000

TYING BEAM NODE   7  TO SHELL NODE   9
OFFSET:    -3.67000

TYING BEAM NODE   8  TO SHELL NODE  10
OFFSET:    -3.67000

                                        C.P. TIME AT BEGINNING OF WRITAR    9.812
                                                  WALL CLOCK 17.34.11.
                                               C.P. TIME AT END  10.076
                                                  WALL CLOCK 17.34.12.

                                C.P.TIME AT START OF TRIANGULARISATION  10.113

                  LN(DETERMINANT)=  .269E+03   SINGULARITY RATIO  .242E+00

                                C.P.TIME AT END OF TRIANGULARISATION  10.602

CPU IN:      8.859, CPU OUT:     11.894, CPU TOTAL:       3.035 OSOLV1


 DATA FOR SUBSTRUCTURE NO   2


NUMEL,NUMNP,NUMBC,MAXBW,NBCTRA,ITIE,IENR1(ISST)
```

```
   A SIMPLE EXAMPLE
   FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

   4   10   28   10    8    4    0

MPRMAX
     2
    1

GENERATED ELEM DATA

* * * * * * * * * *
NELTYP, MTYPE,MNDPTE,ICROUT,ISMALL,  IEXP,  IRHS
     2      0     4      1      0      0      0

TYPE IS   1  WITH 2  NODES AND23  STRAINS AND 1  DIRECT 0  SHEAR STRESS, ISHELL= 1
ROW CORRESPONDENCE FOR EXPANDED MATRIX
232 1 1 1 5 5 3 5 4 0 0 0 0 0 0 222 2 0 1 5 5 3 5 4 0 0 0 0 211 1 0 1 5
INTEL  INTIN  ISNTE  INTPRE
   5     5     3     5
ROWS WITH SECOND ORDER DISPLACEMENT TERMS
   6     0     0     0     0     0

TYPE IS   2  WITH 4  NODES AND33  STRAINS AND 2  DIRECT 1  SHEAR STRESS, ISHELL= 1
ROW CORRESPONDENCE FOR EXPANDED MATRIX
0 6 3 3 0272714 9 6 6 6111111 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
INTEL  INTIN  ISNTE  INTPRE
   9     9     5     9
ROWS WITH SECOND ORDER DISPLACEMENT TERMS
   6     6    11     0     0     0

ICURV  ICTRNS  IBXA  IDBXA  IDEV NBCTRA NUPTRA  IUPDAT MESHR LODCOR
    0      1      0      0     0      0      0      0     5     2

* * * * * * * * * *

BOUNDARY C

NO.OF CARDS FOR B.C.=   28

FSTNO,LASTNO,FST DEG,LST DEG,SPEC.DISP.
   1     1     2     2  0.

FSTNO,LASTNO,FST DEG,LST DEG,SPEC.DISP.
   1     1     4     4  0.

FSTNO,LASTNO,FST DEG,LST DEG,SPEC.DISP.
   1     1     6     6  0.

FSTNO,LASTNO,FST DEG,LST DEG,SPEC.DISP.
   1     1     8     8  0.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    2     2     1     1  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    2     2     3     3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    2     2     5     5  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    2     2     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    3     3     2     2  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    3     3     4     4  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    3     3     6     6  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    3     3     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     1     1  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     3     3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     5     5  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    4     4     8     8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     2     2  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     3     3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     4     4  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
    5     5     6     6  0.
```

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)


FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   5    5    7    7  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   5    5    8    8  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    1    1  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    3    3  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    5    5  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    6    6  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    7    7  0.

FSTND,LASTND,FST DEG,LST DEG,SPEC.DISP.
   6    6    8    8  0.

   28  DEG. OF FREEDOM FIXED
NO  NO  NO   DEG FIX DISP,NO    NO.NO   DEG  FIXED DISP
   1    1    2 0.            2    1    4 0.
   3    1    6 0.            4    1    8 0.
   5    2    1 0.            6    2    3 0.
   7    2    5 0.            8    2    8 0.
   9    3    2 0.           10    3    4 0.
  11    3    6 0.           12    3    8 0.
  13    4    1 0.           14    4    3 0.
  15    4    5 0.           16    4    8 0.
  17    5    2 0.           18    5    3 0.
  19    5    4 0.           20    5    6 0.
  21    5    7 0.           22    5    8 0.
  23    6    1 0.           24    6    3 0.
  25    6    5 0.           26    6    6 0.
  27    6    7 0.           28    6    8 0.

CONNECTIVI

NUMEL1,MESHR1
     4      5

NUMEL  TYPE  NODE NUMBERS ANTICLOCKWISE
   1   20    1    2    4    3
   2   20    3    4    6    5
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
   3   13    7    8    0    0
   4   13    9   10    0    0

COORDINATE

NCRD1=   13  NUMNP1=   10  MESHR1=    5

NPNUM  COORDS
   1   0.00000  17.00000  61.62500   0.00000   0.00000   0.00000
  1.00000   0.00000  17.00000   0.00000   1.00000   0.00000
  0.00000
   2  96.80032  17.00000   0.00000  -1.00000   0.00000  61.62500
  0.00000   0.00000  17.00000   0.00000   1.00000   0.00000
  0.00000
   3   0.00000  28.00000  61.62500   0.00000   0.00000   0.00000
  1.00000   0.00000  28.00000   0.00000   1.00000   0.00000
  0.00000
   4  96.80032  28.00000   0.00000  -1.00000   0.00000  61.62500
  0.00000   0.00000  28.00000   0.00000   1.00000   0.00000
  0.00000
   5   0.00000  39.00000  61.62500   0.00000   0.00000   0.00000
  1.00000   0.00000  39.00000   0.00000   1.00000   0.00000
  0.00000
   6  96.80032  39.00000   0.00000  -1.00000   0.00000  61.62500
  0.00000   0.00000  39.00000   0.00000   1.00000   0.00000
  0.00000
   7  57.95500   0.00000  28.00000   0.00000   1.00000   0.00000
  1.00000   0.00000   0.00000   0.00000    .01725   0.00000
  0.00000
   8   0.00000  57.95500  28.00000  -1.00000   0.00000   0.00000
  0.00000   1.00000   0.00000   -.01725   0.00000   0.00000
 91.03550
   9  57.95500   0.00000  39.00000   0.00000   1.00000   0.00000
  1.00000   0.00000   0.00000   0.00000    .01725   0.00000
  0.00000
  10   0.00000  57.95500  39.00000  -1.00000   0.00000   0.00000
  0.00000   1.00000   0.00000   -.01725   0.00000   0.00000
 91.03550

TRACTIONS

    1  ELEMS WITH DISTRIB. LOAD OF MAGNITUDE   .1000000E+03   AND TYPE 2
     1

    1  ELEMS WITH DISTRIB. LOAD OF MAGNITUDE   .1000000E+03   AND TYPE 2
     2

    0  NODAL LOADS LISTED BELOW
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
 GEOMETRY

 NO OF DISTINCT ELEM. GEOMS =     4
  EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
  .600E+00 0.          0.          0.        0.
 ELEM GEOM FOR ELEM     1  TO      1
  EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
  .600E+00 0.          0.          0.        0.
 ELEM GEOM FOR ELEM     2  TO      2
  EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
 0.          .100E+01 0.           0.        0.
 ELEM GEOM FOR ELEM     3  TO      3
  EGEOM1     EGEOM2    EGEOM3      SINCTP    STAPE
 0.          .200E+01 0.           0.        0.
 ELEM GEOM FOR ELEM     4  TO      4

 PROPERTY
 NO OF DISTINCT ELEM PROP=     4
 YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
  .300E+08   .300E+00 0.        0.          0.          .100E+06 0.
 ELEM PROPS FROM ELEM     1  TO     1
 YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
  .300E+08   .300E+00 0.        0.          0.          .100E+05 0.
 ELEM PROPS FROM ELEM     2  TO     2
 YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
  .300E+08   .300E+00 0.        0.          0.          .100E+06 0.
 ELEM PROPS FROM ELEM     3  TO     3
 YOUNGS MOD.,POISSON R.,DENSITY, ALPHA,TOT.TEMP., YIELP,, YIELP2
  .300E+08   .300E+00 0.        0.          0.          .100E+06 0.
 ELEM PROPS FROM ELEM     4  TO     4

 TYING

 NO. TIED NODES     4

 TIE TYPE,NO.RETAINED NODES
   19    2

 TIE NO  1  TYPE 19  TIED NODE  7  NO.RET.NODES  2
 RETAINED NODES     3     4

 TIE NO  2  TYPE 19  TIED NODE  8  NO.RET.NODES  2
 RETAINED NODES     4     3

 TIE NO  3  TYPE 19  TIED NODE  9  NO.RET.NODES  2
 RETAINED NODES     5     6

 TIE NO  4  TYPE 19  TIED NODE 10  NO.RET.NODES  2
 RETAINED NODES     6     5
```

```
   A SIMPLE EXAMPLE
   FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)


END OPTION

CPU IN:      11.931, CPU OUT:      12.892, CPU TOTAL:        .961 OAREAD


   2 BOUNDARY NODES     8 INTERIOR NODES

LIST OF BOUNDARY NODES
   1    2


CPU IN:      13.319, CPU OUT:      13.600, CPU TOTAL:        .281 OPRESS



CPU IN:      13.616, CPU OUT:      19.047, CPU TOTAL:       5.431 OASEMB



NEW ITIX

    1     5     1     2
    2     6     2     1
    3     7     3     4
    4     8     4     3

TYING BEAM NODE    5   TO SHELL NODE    1
OFFSET:    -3.67000

TYING BEAM NODE    6   TO SHELL NODE    2
OFFSET:    -3.67000

TYING BEAM NODE    7   TO SHELL NODE    3
OFFSET:    -3.67000

TYING BEAM NODE    8   TO SHELL NODE    4
OFFSET:    -3.67000

                                                 C.P. TIME AT BEGINNING OF WRITAR  20.018
                                                             WALL CLOCK 17.34.34.
                                                         C.P. TIME AT END  20.275
                                                            WALL CLOCK 17.34.35.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
                                         C.P.TIME AT START OF TRIANGULARISATION  20.301


                  LN(DETERMINANT)=  .306E+03  SINGULARITY RATIO  .233E+00

                                         C.P.TIME AT END OF TRIANGULARISATION  21.419

CPU IN:      19.067, CPU OUT:      23.445, CPU TOTAL:       4.378 OSOLV1

LAST WRITE TAPES
   2    8
NO OF SKIP READS FOR EACH SUBST
    8      8


CONNECTIONS BETWEEN SUBSTRUCTURES

   2    2
START OF STRUCTURE CONNECTIONS
NO OF CONNECTIONS,START OF NON ZERO CONN.
   2    1
NO OF CONNECTIONS,START OF NON ZERO CONN.
   2    1

                                   C.P. TIME AT BEGINNING OF WRITAR  23.553
                                                WALL CLOCK 17.34.43.
                                            C.P. TIME AT END  23.614
                                              WALL CLOCK 17.34.44.

                                         C.P.TIME AT START OF TRIANGULARISATION  23.617


                  LN(DETERMINANT)=  .193E+03  SINGULARITY RATIO  .433E+00

                                         C.P.TIME AT END OF TRIANGULARISATION  23.669

DISPLACEMENTS BOUNDARY NODES

-.126E-01 0.    -.650E-04 0.    -.214E-03 0.     .211E-02 0.       -.952E-04
```

```
0.          .214E-03 0.       -.126E-01 0.       -.650E-04  .211E-02 0.       -.952E-04

CPU IN:      23.469, CPU OUT:      23.692, CPU TOTAL:        .223 OCONTB



RESULTS FOR SUBSTRUCTURE NO    1


    2      0      0


TYING BEAM NODE  10   TO SHELL NODE    6
OFFSET:    -3.67000

TYING BEAM NODE   9   TO SHELL NODE    5
OFFSET:    -3.67000

TYING BEAM NODE   8   TO SHELL NODE    4
OFFSET:    -3.67000

TYING BEAM NODE   7   TO SHELL NODE    3
OFFSET:    -3.67000

CPU IN:      23.933, CPU OUT:      24.086, CPU TOTAL:        .153 OSOLV3



RESULTS AFTER ITERATION      1 OF      3
ESTIMATED  DISPLACEMENT:              .4049002910E-02
CALCULATED DISPLACEMENT:              .4049002910E-02
PERCENT  DIFFERENCE (FACR*100):          0.
PREVIOUS DIFFERENCE:                     10.000

CPU IN:      24.105, CPU OUT:      29.000, CPU TOTAL:      4.895 OGETST



RESULTS FOR SUBSTRUCTURE NO    2


    2      0      0
```

```
A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)


TYING BEAM NODE  10  TO SHELL NODE   6
OFFSET:    -3.67000

TYING BEAM NODE   9  TO SHELL NODE   5
OFFSET:    -3.67000

TYING BEAM NODE   8  TO SHELL NODE   4
OFFSET:    -3.67000

TYING BEAM NODE   7  TO SHELL NODE   3
OFFSET:    -3.67000

CPU IN:     29.431, CPU OUT:     29.613, CPU TOTAL:       .182 OSOLV3



CPU IN:     29.629, CPU OUT:     34.443, CPU TOTAL:      4.814 OGETST



RESULTS FOR SUBSTRUCTURE NO    1


    2     0     0

SOLUTION SCALED BY  .100E+01  TO CAUSE FIRST YIELD IN ELEMENT    1  IF SCALING WAS REQUESTED



                                     E L E M E N T   D A T A
             I N V A R I A N T S                                      C O M P O N E N T S
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

ELEMENT NUMBER / LYR. NO.	POINT NUMBER / TOTAL EQUIV. J2 TENSILE STRESS	TOTAL MEAN NORMAL STRESS	TOTAL EQUIV. PLASTIC STRAIN	TOTAL EQUIV. CREEP STRAIN	TOTAL TEMPERATURE	INCREMENTAL STRAIN COMPONENTS / TOTAL STRESS COMPONENTS NO.1	NO.2	NO.3	NO.4	NO.5	NO
1	1					-.4197E-05	-.1558E-03	-.3203E-04	-.4239E-07	.7801E-03	.3287
1	.2371E+04	0.	0.	0.	0.	.6315E+03	.2536E+04	-.3623E+03			
2	.1116E+04	0.	0.	0.	0.	.1686E+03	.9925E+03	-.3646E+03			
3	.7947E+03	0.	0.	0.	0.	-.2943E+03	-.5506E+03	-.3669E+03			
4	.1944E+04	0.	0.	0.	0.	-.7571E+03	-.2094E+04	-.3692E+03			
5	.3270E+04	0.	0.	0.	0.	-.1220E+04	-.3637E+04	-.3715E+03			
6	.4622E+04	0.	0.	0.	0.	-.1683E+04	-.5180E+04	-.3738E+03			
7	.5984E+04	0.	0.	0.	0.	-.2146E+04	-.6723E+04	-.3761E+03			
8	.7349E+04	0.	0.	0.	0.	-.2609E+04	-.8266E+04	-.3784E+03			
9	.8716E+04	0.	0.	0.	0.	-.3071E+04	-.9809E+04	-.3807E+03			
10	.1008E+05	0.	0.	0.	0.	-.3534E+04	-.1135E+05	-.3830E+03			
11	.1145E+05	0.	0.	0.	0.	-.3997E+04	-.1290E+05	-.3853E+03			
1	2					-.2505E-05	-.1558E-03	.2096E-17	-.7584E-07	.8654E-03	-.9487
1	.3037E+04	0.	0.	0.	0.	.9426E+03	.3396E+04	.2096E-10			
2	.1516E+04	0.	0.	0.	0.	.4292E+03	.1684E+04	.2162E-10			
3	.7443E+02	0.	0.	0.	0.	-.8422E+02	-.2726E+02	.2228E-10			
4	.1530E+04	0.	0.	0.	0.	-.5976E+03	-.1739E+04	.2294E-10			
5	.3851E+04	0.	0.	0.	0.	-.1111E+04	-.3451E+04	.2360E-10			
6	.4572E+04	0.	0.	0.	0.	-.1624E+04	-.5162E+04	.2425E-10			
7	.6093E+04	0.	0.	0.	0.	-.2138E+04	-.6874E+04	.2491E-10			
8	.7615E+04	0.	0.	0.	0.	-.2651E+04	-.8586E+04	.2557E-10			
9	.9136E+04	0.	0.	0.	0.	-.3165E+04	-.1030E+05	.2523E-10			
10	.1066E+05	0.	0.	0.	0.	-.3678E+04	-.1201E+05	.2589E-10			
11	.1218E+05	0.	0.	0.	0.	-.4191E+04	-.1372E+05	.2755E-10			
1	3					-.4197E-05	-.1558E-03	.3203E-04	-.4239E-07	.7861E-03	-.3287
1	.2371E+04	0.	0.	0.	0.	.6315E+03	.2536E+04	.3623E+03			
2	.1116E+04	0.	0.	0.	0.	.1686E+03	.9925E+03	.3646E+03			
3	.7947E+03	0.	0.	0.	0.	-.2943E+03	-.5506E+03	.3669E+03			
4	.1944E+04	0.	0.	0.	0.	-.7571E+03	-.2094E+04	.3692E+03			
5	.3270E+04	0.	0.	0.	0.	-.1220E+04	-.3637E+04	.3715E+03			
6	.4622E+04	0.	0.	0.	0.	-.1683E+04	-.5180E+04	.3738E+03			
7	.5984E+04	0.	0.	0.	0.	-.2146E+04	-.6723E+04	.3761E+03			
8	.7349E+04	0.	0.	0.	0.	-.2609E+04	-.8266E+04	.3784E+03			
9	.8716E+04	0.	0.	0.	0.	-.3071E+04	-.9809E+04	.3807E+03			
10	.1008E+05	0.	0.	0.	0.	-.3534E+04	-.1135E+05	.3830E+03			
11	.1145E+05	0.	0.	0.	0.	-.3997E+04	-.1290E+05	.3853E+03			
1	4					-.6160E-04	-.1406E-03	-.3447E-04	-.7125E-06	.2159E-03	.5336

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
  1   .3055E+04  0.        0.        0.        0.        -.2835E+04  -.3127E+04  -.3837E+03
  2   .3365E+04  0.        0.        0.        0.        -.2962E+04  -.3553E+04  -.3874E+03
  3   .3681E+04  0.        0.        0.        0.        -.3089E+04  -.3980E+04  -.3911E+03
  4   .4007E+04  0.        0.        0.        0.        -.3215E+04  -.4407E+04  -.3949E+03
  5   .4342E+04  0.        0.        0.        0.        -.3342E+04  -.4833E+04  -.3986E+03
  6   .4684E+04  0.        0.        0.        0.        -.3469E+04  -.5260E+04  -.4023E+03
  7   .5031E+04  0.        0.        0.        0.        -.3595E+04  -.5686E+04  -.4061E+03
  8   .5383E+04  0.        0.        0.        0.        -.3722E+04  -.6113E+04  -.4098E+03
  9   .5738E+04  0.        0.        0.        0.        -.3849E+04  -.6540E+04  -.4135E+03
 10   .6096E+04  0.        0.        0.        0.        -.3975E+04  -.6966E+04  -.4173E+03
 11   .6457E+04  0.        0.        0.        0.        -.4102E+04  -.7393E+04  -.4210E+03

    1          5                                       -.4176E-04  -.1406E-03  -.2001E-16  -.1076E-05   .1602E-03  -.1922
  1   .3860E+04  0.        0.        0.        0.        -.2312E+04  -.3471E+04  -.2832E-09
  2   .3319E+04  0.        0.        0.        0.        -.2405E+04  -.3787E+04  -.2851E-09
  3   .3581E+04  0.        0.        0.        0.        -.2497E+04  -.4103E+04  -.2869E-09
  4   .3846E+04  0.        0.        0.        0.        -.2590E+04  -.4419E+04  -.2888E-09
  5   .4113E+04  0.        0.        0.        0.        -.2683E+04  -.4736E+04  -.2906E-09
  6   .4382E+04  0.        0.        0.        0.        -.2776E+04  -.5052E+04  -.2924E-09
  7   .4653E+04  0.        0.        0.        0.        -.2869E+04  -.5368E+04  -.2943E-09
  8   .4924E+04  0.        0.        0.        0.        -.2962E+04  -.5685E+04  -.2961E-09
  9   .5197E+04  0.        0.        0.        0.        -.3055E+04  -.6001E+04  -.2980E-09
 10   .5471E+04  0.        0.        0.        0.        -.3148E+04  -.6317E+04  -.2998E-09
 11   .5745E+04  0.        0.        0.        0.        -.3241E+04  -.6633E+04  -.3017E-09

    1          6                                       -.6160E-04  -.1406E-03   .3447E-04  -.7125E-06   .2159E-03  -.5336
  1   .3065E+04  0.        0.        0.        0.        -.2835E+04  -.3127E+04   .3837E+03
  2   .3365E+04  0.        0.        0.        0.        -.2962E+04  -.3553E+04   .3874E+03
  3   .3681E+04  0.        0.        0.        0.        -.3089E+04  -.3980E+04   .3911E+03
  4   .4007E+04  0.        0.        0.        0.        -.3215E+04  -.4407E+04   .3949E+03
  5   .4342E+04  0.        0.        0.        0.        -.3342E+04  -.4833E+04   .3986E+03
  6   .4684E+04  0.        0.        0.        0.        -.3469E+04  -.5260E+04   .4023E+03
  7   .5031E+04  0.        0.        0.        0.        -.3595E+04  -.5686E+04   .4061E+03
  8   .5383E+04  0.        0.        0.        0.        -.3722E+04  -.6113E+04   .4098E+03
  9   .5738E+04  0.        0.        0.        0.        -.3849E+04  -.6540E+04   .4135E+03
 10   .6096E+04  0.        0.        0.        0.        -.3975E+04  -.6966E+04   .4173E+03
 11   .6457E+04  0.        0.        0.        0.        -.4102E+04  -.7393E+04   .4210E+03

    1          7                                       -.1278E-03  -.1210E-03   .1298E-03  -.1860E-05  -.3484E-03  -.6942
  1   .8287E+04  0.        0.        0.        0.        -.6561E+04  -.8733E+04   .1490E+04
  2   .7787E+04  0.        0.        0.        0.        -.6350E+04  -.8043E+04   .1495E+04
  3   .7305E+04  0.        0.        0.        0.        -.6140E+04  -.7352E+04   .1500E+04
  4   .6844E+04  0.        0.        0.        0.        -.5929E+04  -.6662E+04   .1505E+04
  5   .6408E+04  0.        0.        0.        0.        -.5719E+04  -.5972E+04   .1510E+04
  6   .6002E+04  0.        0.        0.        0.        -.5508E+04  -.5282E+04   .1515E+04
  7   .5635E+04  0.        0.        0.        0.        -.5298E+04  -.4592E+04   .1520E+04
  8   .5313E+04  0.        0.        0.        0.        -.5087E+04  -.3902E+04   .1524E+04
  9   .5045E+04  0.        0.        0.        0.        -.4877E+04  -.3211E+04   .1529E+04
 10   .4840E+04  0.        0.        0.        0.        -.4666E+04  -.2521E+04   .1534E+04
```

A SIMPLE EXAMPLE

FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

11	-.4707E+04	0.	0.	0.	0.	-.4456E+04	-.1831E+04	.1539E+04			
	1	8				-.1078E-03	-.1210E-03	-.1801E-16	-.2076E-05	-.5450E-03	.6776
1	.9132E+04	0.	0.	0.	0.	-.6408E+04	-.1046E+05	-.2083E-09			
2	.8239E+04	0.	0.	0.	0.	-.6081E+04	-.9377E+04	-.2086E-09			
3	.7363E+04	0.	0.	0.	0.	-.5753E+04	-.8298E+04	-.2089E-09			
4	.6510E+04	0.	0.	0.	0.	-.5426E+04	-.7219E+04	-.2092E-09			
5	.5691E+04	0.	0.	0.	0.	-.5098E+04	-.6140E+04	-.2095E-09			
6	.4922E+04	0.	0.	0.	0.	-.4771E+04	-.5061E+04	-.2098E-09			
7	.4231E+04	0.	0.	0.	0.	-.4443E+04	-.3982E+04	-.2101E-09			
8	.3663E+04	0.	0.	0.	0.	-.4116E+04	-.2902E+04	-.2103E-09			
9	.3282E+04	0.	0.	0.	0.	-.3788E+04	-.1823E+04	-.2106E-09			
10	.3155E+04	0.	0.	0.	0.	-.3461E+04	-.7440E+03	-.2109E-09			
11	.3314E+04	0.	0.	0.	0.	-.3133E+04	.3352E+03	-.2112E-09			
	1	9				-.1278E-03	-.1210E-03	-.1298E-03	-.1860E-05	-.3484E-03	.6942
1	.8287E+04	0.	0.	0.	0.	-.6561E+04	-.8733E+04	-.1490E+04			
2	.7787E+04	0.	0.	0.	0.	-.6350E+04	-.8043E+04	-.1495E+04			
3	.7305E+04	0.	0.	0.	0.	-.6140E+04	-.7352E+04	-.1500E+04			
4	.6844E+04	0.	0.	0.	0.	-.5929E+04	-.6662E+04	-.1505E+04			
5	.6408E+04	0.	0.	0.	0.	-.5719E+04	-.5972E+04	-.1510E+04			
6	.6002E+04	0.	0.	0.	0.	-.5508E+04	-.5282E+04	-.1515E+04			
7	.5635E+04	0.	0.	0.	0.	-.5298E+04	-.4592E+04	-.1520E+04			
8	.5313E+04	0.	0.	0.	0.	-.5087E+04	-.3902E+04	-.1524E+04			
9	.5045E+04	0.	0.	0.	0.	-.4877E+04	-.3211E+04	-.1529E+04			
10	.4840E+04	0.	0.	0.	0.	-.4666E+04	-.2521E+04	-.1534E+04			
11	.4707E+04	0.	0.	0.	0.	-.4456E+04	-.1831E+04	-.1539E+04			
	2	1				-.1498E-03	-.1096E-03	.1281E-03	-.2781E-05	-.2307E-03	-.7783
1	.7590E+04	0.	0.	0.	0.	-.6850E+04	-.7420E+04	.1467E+04			
2	.7299E+04	0.	0.	0.	0.	-.6707E+04	-.6962E+04	.1473E+04			
3	.7019E+04	0.	0.	0.	0.	-.6565E+04	-.6504E+04	.1478E+04			
4	.6751E+04	0.	0.	0.	0.	-.6422E+04	-.6046E+04	.1484E+04			
5	.6498E+04	0.	0.	0.	0.	-.6280E+04	-.5588E+04	.1489E+04			
6	.6261E+04	0.	0.	0.	0.	-.6137E+04	-.5130E+04	.1495E+04			
7	.6042E+04	0.	0.	0.	0.	-.5995E+04	-.4672E+04	.1500E+04			
8	.5844E+04	0.	0.	0.	0.	-.5852E+04	-.4215E+04	.1506E+04			
9	.5667E+04	0.	0.	0.	0.	-.5710E+04	-.3757E+04	.1511E+04			
10	.5515E+04	0.	0.	0.	0.	-.5567E+04	-.3299E+04	.1517E+04			
11	.5389E+04	0.	0.	0.	0.	-.5425E+04	-.2841E+04	.1522E+04			
	2	2				-.1595E-03	-.1096E-03	-.1936E-16	-.2186E-05	-.1324E-03	.3482
1	.6657E+04	0.	0.	0.	0.	-.6788E+04	-.6517E+04	-.2106E-09			
2	.6492E+04	0.	0.	0.	0.	-.6705E+04	-.6254E+04	-.2130E-09			
3	.6330E+04	0.	0.	0.	0.	-.6622E+04	-.5991E+04	-.2155E-09			
4	.6174E+04	0.	0.	0.	0.	-.6539E+04	-.5728E+04	-.2179E-09			
5	.6022E+04	0.	0.	0.	0.	-.6456E+04	-.5464E+04	-.2204E-09			
6	.5876E+04	0.	0.	0.	0.	-.6374E+04	-.5201E+04	-.2228E-09			
7	.5735E+04	0.	0.	0.	0.	-.6291E+04	-.4938E+04	-.2253E-09			

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
  8   .5604E+04  0.          0.          0.          0.          -.6208E+04  -.4675E+04  -.2278E-09
  9   .5473E+04  0.          0.          0.          0.          -.6125E+04  -.4412E+04  -.2302E-09
 10   .5352E+04  0.          0.          0.          0.          -.6042E+04  -.4148E+04  -.2327E-09
 11   .5239E+04  0.          0.          0.          0.          -.5959E+04  -.3885E+04  -.2351E-09

    2         3                                                  -.1498E-03  -.1096E-03  -.1281E-03  -.2781E-05  -.2307E-03   .7783
  1   .7590E+04  0.          0.          0.          0.          -.6850E+04  -.7420E+04  -.1467E+04
  2   .7299E+04  0.          0.          0.          0.          -.6707E+04  -.6962E+04  -.1473E+04
  3   .7019E+04  0.          0.          0.          0.          -.6565E+04  -.6504E+04  -.1478E+04
  4   .6751E+04  0.          0.          0.          0.          -.6422E+04  -.6046E+04  -.1484E+04
  5   .6498E+04  0.          0.          0.          0.          -.6280E+04  -.5588E+04  -.1489E+04
  6   .6261E+04  0.          0.          0.          0.          -.6137E+04  -.5130E+04  -.1495E+04
  7   .6042E+04  0.          0.          0.          0.          -.5995E+04  -.4672E+04  -.1500E+04
  8   .5844E+04  0.          0.          0.          0.          -.5852E+04  -.4215E+04  -.1506E+04
  9   .5657E+04  0.          0.          0.          0.          -.5710E+04  -.3757E+04  -.1511E+04
 10   .5515E+04  0.          0.          0.          0.          -.5567E+04  -.3299E+04  -.1517E+04
 11   .5389E+04  0.          0.          0.          0.          -.5425E+04  -.2841E+04  -.1522E+04

    2         4                                                  -.1845E-03  -.9828E-04  -.3658E-04  -.3549E-05  -.1121E-03   .3096
  1   .7028E+04  0.          0.          0.          0.          -.7563E+04  -.6226E+04  -.4161E+03
  2   .6906E+04  0.          0.          0.          0.          -.7489E+04  -.6003E+04  -.4183E+03
  3   .6787E+04  0.          0.          0.          0.          -.7416E+04  -.5779E+04  -.4205E+03
  4   .6672E+04  0.          0.          0.          0.          -.7342E+04  -.5555E+04  -.4226E+03
  5   .6561E+04  0.          0.          0.          0.          -.7268E+04  -.5331E+04  -.4248E+03
  6   .6453E+04  0.          0.          0.          0.          -.7195E+04  -.5107E+04  -.4270E+03
  7   .6351E+04  0.          0.          0.          0.          -.7121E+04  -.4883E+04  -.4291E+03
  8   .6252E+04  0.          0.          0.          0.          -.7047E+04  -.4659E+04  -.4313E+03
  9   .6159E+04  0.          0.          0.          0.          -.6973E+04  -.4435E+04  -.4335E+03
 10   .6071E+04  0.          0.          0.          0.          -.6900E+04  -.4211E+04  -.4356E+03
 11   .5987E+04  0.          0.          0.          0.          -.6826E+04  -.3987E+04  -.4378E+03

    2         5                                                  -.2033E-03  -.9828E-04  -.3334E-17  -.2641E-05  -.8322E-04   .5678
  1   .7229E+04  0.          0.          0.          0.          -.7987E+04  -.6093E+04  -.7591E-10
  2   .7144E+04  0.          0.          0.          0.          -.7933E+04  -.5927E+04  -.7994E-10
  3   .7052E+04  0.          0.          0.          0.          -.7878E+04  -.5761E+04  -.8298E-10
  4   .6981E+04  0.          0.          0.          0.          -.7823E+04  -.5595E+04  -.8601E-10
  5   .6903E+04  0.          0.          0.          0.          -.7769E+04  -.5429E+04  -.8904E-10
  6   .6827E+04  0.          0.          0.          0.          -.7714E+04  -.5263E+04  -.9207E-10
  7   .6753E+04  0.          0.          0.          0.          -.7659E+04  -.5096E+04  -.9511E-10
  8   .6682E+04  0.          0.          0.          0.          -.7605E+04  -.4930E+04  -.9814E-10
  9   .6613E+04  0.          0.          0.          0.          -.7550E+04  -.4764E+04  -.1012E-09
 10   .6547E+04  0.          0.          0.          0.          -.7496E+04  -.4598E+04  -.1042E-09
 11   .6483E+04  0.          0.          0.          0.          -.7441E+04  -.4432E+04  -.1072E-09

    2         6                                                  -.1845E-03  -.9828E-04   .3658E-04  -.3549E-05  -.1121E-03  -.3096
  1   .7028E+04  0.          0.          0.          0.          -.7563E+04  -.6226E+04   .4161E+03
  2   .6906E+04  0.          0.          0.          0.          -.7489E+04  -.6003E+04   .4183E+03
  3   .6787E+04  0.          0.          0.          0.          -.7416E+04  -.5779E+04   .4205E+03
  4   .6672E+04  0.          0.          0.          0.          -.7342E+04  -.5555E+04   .4226E+03
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

5	.6551E+04	0.	0.	0.	0.	-.7268E+04	-.5331E+04	.4248E+03			
6	.6453E+04	0.	0.	0.	0.	-.7195E+04	-.5107E+04	.4270E+03			
7	.6351E+04	0.	0.	0.	0.	-.7121E+04	-.4883E+04	.4291E+03			
8	.6252E+04	0.	0.	0.	0.	-.7047E+04	-.4659E+04	.4313E+03			
9	.6159E+04	0.	0.	0.	0.	-.6973E+04	-.4435E+04	.4335E+03			
10	.6071E+04	0.	0.	0.	0.	-.6900E+04	-.4211E+04	.4356E+03			
11	.5987E+04	0.	0.	0.	0.	-.6826E+04	-.3987E+04	.4378E+03			
	2 7					-.2037E-03	-.9478E-04	-.2501E-04	-.3484E-05	.6388E-05	.1957
1	.6906E+04	0.	0.	0.	0.	-.7826E+04	-.5134E+04	-.2967E+03			
2	.6905E+04	0.	0.	0.	0.	-.7823E+04	-.5144E+04	-.2981E+03			
3	.6905E+04	0.	0.	0.	0.	-.7819E+04	-.5155E+04	-.299-E+03			
4	.6905E+04	0.	0.	0.	0.	-.7816E+04	-.5165E+04	-.3008E+03			
5	.6904E+04	0.	0.	0.	0.	-.7813E+04	-.5176E+04	-.3022E+03			
6	.6904E+04	0.	0.	0.	0.	-.7810E+04	-.5186E+04	-.3035E+03			
7	.6903E+04	0.	0.	0.	0.	-.7806E+04	-.5197E+04	-.3049E+03			
8	.6903E+04	0.	0.	0.	0.	-.7803E+04	-.5207E+04	-.3063E+03			
9	.6903E+04	0.	0.	0.	0.	-.7800E+04	-.5218E+04	-.3077E+03			
10	.6903E+04	0.	0.	0.	0.	-.7797E+04	-.5229E+04	-.3090E+03			
11	.6902E+04	0.	0.	0.	0.	-.7793E+04	-.5239E+04	-.310-E+03			
	2 8					-.2004E-03	-.9478E-04	-.3449E-17	-.3096E-05	-.3461E-04	.2286
1	.6873E+04	0.	0.	0.	0.	-.7716E+04	-.5465E+04	-.4836E-10			
2	.6838E+04	0.	0.	0.	0.	-.7690E+04	-.5395E+04	-.4983E-10			
3	.6803E+04	0.	0.	0.	0.	-.7663E+04	-.5326E+04	-.5129E-10			
4	.6759E+04	0.	0.	0.	0.	-.7637E+04	-.5257E+04	-.5276E-10			
5	.6735E+04	0.	0.	0.	0.	-.7611E+04	-.5188E+04	-.5423E-10			
6	.6701E+04	0.	0.	0.	0.	-.7584E+04	-.5119E+04	-.5570E-10			
7	.6668E+04	0.	0.	0.	0.	-.7558E+04	-.5050E+04	-.5717E-10			
8	.6635E+04	0.	0.	0.	0.	-.7532E+04	-.4981E+04	-.586-E-10			
9	.6602E+04	0.	0.	0.	0.	-.7505E+04	-.4911E+04	-.6011E-10			
10	.6570E+04	0.	0.	0.	0.	-.7479E+04	-.4842E+04	-.6157E-10			
11	.6539E+04	0.	0.	0.	0.	-.7453E+04	-.4773E+04	-.6304E-10			
	2 9					-.2037E-03	-.9478E-04	.2501E-04	-.3484E-05	.6388E-05	-.1957
1	.6906E+04	0.	0.	0.	0.	-.7826E+04	-.5134E+04	.2967E+03			
2	.6905E+04	0.	0.	0.	0.	-.7823E+04	-.5144E+04	.2981E+03			
3	.6905E+04	0.	0.	0.	0.	-.7819E+04	-.5155E+04	.299-E+03			
4	.6905E+04	0.	0.	0.	0.	-.7816E+04	-.5165E+04	.3008E+03			
5	.6904E+04	0.	0.	0.	0.	-.7813E+04	-.5176E+04	.3022E+03			
6	.6904E+04	0.	0.	0.	0.	-.7810E+04	-.5186E+04	.3035E+03			
7	.6903E+04	0.	0.	0.	0.	-.7806E+04	-.5197E+04	.3049E+03			
8	.6903E+04	0.	0.	0.	0.	-.7803E+04	-.5207E+04	.3063E+03			
9	.6903E+04	0.	0.	0.	0.	-.7800E+04	-.5218E+04	.3077E+03			
10	.6903E+04	0.	0.	0.	0.	-.7797E+04	-.5229E+04	.3090E+03			
11	.6902E+04	0.	0.	0.	0.	-.7793E+04	-.5239E+04	.310-E+03			

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

E L E M E N T   D A T A

I N V A R I A N T S   /   C O M P O N E N T S

ELEMENT NUMBER	POINT NUMBER					INCREMENTAL STRAIN COMPONENTS NO.1	NO.2	NO.3	NO.4	NO.5	NO
LYR. NO.	TOTAL EQUIV. J2 TENSILE STRESS	TOTAL MEAN NORMAL STRESS	TOTAL EQUIV. PLASTIC STRAIN	TOTAL EQUIV. CREEP STRAIN	TOTAL TEMPERATURE	TOTAL STRESS COMPONENTS NO.1	NO.2	NO.3	NO.4	NO.5	NO
3	1					-.1529E-03	-.9635E-07	-.4508E-18	.4565E-21	-.9225E-18	0.
1	.4587E+04	0.	0.	0.	0.	-.4587E+04					
2	.4587E+04	0.	0.	0.	0.	-.4587E+04					
3	.4587E+04	0.	0.	0.	0.	-.4587E+04					
4	.4587E+04	0.	0.	0.	0.	-.4587E+04					
5	.4587E+04	0.	0.	0.	0.	-.4587E+04					
6	.4587E+04	0.	0.	0.	0.	-.4587E+04					
7	.4587E+04	0.	0.	0.	0.	-.4587E+04					
8	.4587E+04	0.	0.	0.	0.	-.4587E+04					
9	.4587E+04	0.	0.	0.	0.	-.4587E+04					
10	.4587E+04	0.	0.	0.	0.	-.4587E+04					
11	.4587E+04	0.	0.	0.	0.	-.4587E+04					
12	.4587E+04	0.	0.	0.	0.	-.4587E+04					
13	.4587E+04	0.	0.	0.	0.	-.4587E+04					
14	.4586E+04	0.	0.	0.	0.	-.4586E+04					
15	.4585E+04	0.	0.	0.	0.	-.4585E+04					
16	.4584E+04	0.	0.	0.	0.	-.4584E+04					
17	.4583E+04	0.	0.	0.	0.	-.4583E+04					
18	.4582E+04	0.	0.	0.	0.	-.4582E+04					
19	.4581E+04	0.	0.	0.	0.	-.4581E+04					
20	.4580E+04	0.	0.	0.	0.	-.4580E+04					
21	.4579E+04	0.	0.	0.	0.	-.4579E+04					
22	.4578E+04	0.	0.	0.	0.	-.4578E+04					
23	.4577E+04	0.	0.	0.	0.	-.4577E+04					
3	2					-.1421E-03	.5568E-07	-.2846E-18	-.5464E-21	-.1023E-17	0.
1	.4264E+04	0.	0.	0.	0.	-.4264E+04					

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
  2  .4264E+04  0.          0.          0.          0.          -.4264E+04
  3  .4264E+04  0.          0.          0.          0.          -.4264E+04
  4  .4264E+04  0.          0.          0.          0.          -.4264E+04
  5  .4264E+04  0.          0.          0.          0.          -.4264E+04
  6  .4264E+04  0.          0.          0.          0.          -.4264E+04
  7  .4264E+04  0.          0.          0.          0.          -.4264E+04
  8  .4264E+04  0.          0.          0.          0.          -.4264E+04
  9  .4264E+04  0.          0.          0.          0.          -.4264E+04
 10  .4264E+04  0.          0.          0.          0.          -.4264E+04
 11  .4264E+04  0.          0.          0.          0.          -.4264E+04
 12  .4264E+04  0.          0.          0.          0.          -.4264E+04
 13  .4264E+04  0.          0.          0.          0.          -.4264E+04
 14  .4264E+04  0.          0.          0.          0.          -.4264E+04
 15  .4265E+04  0.          0.          0.          0.          -.4265E+04
 16  .4265E+04  0.          0.          0.          0.          -.4265E+04
 17  .4266E+04  0.          0.          0.          0.          -.4266E+04
 18  .4266E+04  0.          0.          0.          0.          -.4266E+04
 19  .4267E+04  0.          0.          0.          0.          -.4267E+04
 20  .4268E+04  0.          0.          0.          0.          -.4268E+04
 21  .4268E+04  0.          0.          0.          0.          -.4268E+04
 22  .4269E+04  0.          0.          0.          0.          -.4269E+04
 23  .4269E+04  0.          0.          0.          0.          -.4269E+04

   3        3                                                   -.1366E-03  .8285E-07  0.         0.         -.9622E-18  0.
  1  .4098E+04  0.          0.          0.          0.          -.4098E+04
  2  .4098E+04  0.          0.          0.          0.          -.4098E+04
  3  .4098E+04  0.          0.          0.          0.          -.4098E+04
  4  .4098E+04  0.          0.          0.          0.          -.4098E+04
  5  .4098E+04  0.          0.          0.          0.          -.4098E+04
  6  .4098E+04  0.          0.          0.          0.          -.4098E+04
  7  .4098E+04  0.          0.          0.          0.          -.4098E+04
  8  .4098E+04  0.          0.          0.          0.          -.4098E+04
  9  .4098E+04  0.          0.          0.          0.          -.4098E+04
 10  .4098E+04  0.          0.          0.          0.          -.4098E+04
 11  .4098E+04  0.          0.          0.          0.          -.4098E+04
 12  .4098E+04  0.          0.          0.          0.          -.4098E+04
 13  .4098E+04  0.          0.          0.          0.          -.4098E+04
 14  .4099E+04  0.          0.          0.          0.          -.4099E+04
 15  .4100E+04  0.          0.          0.          0.          -.4100E+04
 16  .4101E+04  0.          0.          0.          0.          -.4101E+04
 17  .4102E+04  0.          0.          0.          0.          -.4102E+04
 18  .4103E+04  0.          0.          0.          0.          -.4103E+04
 19  .4103E+04  0.          0.          0.          0.          -.4103E+04
 20  .4104E+04  0.          0.          0.          0.          -.4104E+04
 21  .4105E+04  0.          0.          0.          0.          -.4105E+04
 22  .4106E+04  0.          0.          0.          0.          -.4106E+04
 23  .4107E+04  0.          0.          0.          0.          -.4107E+04

   3        4                                                   -.1421E-03  .5568E-07  .2946E-18  .6287E-21  -.9771E-18  0.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

1	.4264E+04	0.	0.	0.	0.	-.4264E+04
2	.4264E+04	0.	0.	0.	0.	-.4264E+04
3	.4264E+04	0.	0.	0.	0.	-.4264E+04
4	.4264E+04	0.	0.	0.	0.	-.4264E+04
5	.4264E+04	0.	0.	0.	0.	-.4264E+04
6	.4264E+04	0.	0.	0.	0.	-.4264E+04
7	.4264E+04	0.	0.	0.	0.	-.4264E+04
8	.4264E+04	0.	0.	0.	0.	-.4264E+04
9	.4264E+04	0.	0.	0.	0.	-.4264E+04
10	.4264E+04	0.	0.	0.	0.	-.4264E+04
11	.4264E+04	0.	0.	0.	0.	-.4264E+04
12	.4264E+04	0.	0.	0.	0.	-.4264E+04
13	.4264E+04	0.	0.	0.	0.	-.4264E+04
14	.4264E+04	0.	0.	0.	0.	-.4264E+04
15	.4265E+04	0.	0.	0.	0.	-.4265E+04
16	.4265E+04	0.	0.	0.	0.	-.4265E+04
17	.4266E+04	0.	0.	0.	0.	-.4266E+04
18	.4266E+04	0.	0.	0.	0.	-.4266E+04
19	.4267E+04	0.	0.	0.	0.	-.4267E+04
20	.4268E+04	0.	0.	0.	0.	-.4268E+04
21	.4268E+04	0.	0.	0.	0.	-.4268E+04
22	.4269E+04	0.	0.	0.	0.	-.4269E+04
23	.4269E+04	0.	0.	0.	0.	-.4269E+04

3 5 -.1529E-03 -.9635E-07 .4508E-18 -.3741E-21 -.9445E-18 0.

1	.4587E+04	0.	0.	0.	0.	-.4587E+04
2	.4587E+04	0.	0.	0.	0.	-.4587E+04
3	.4587E+04	0.	0.	0.	0.	-.4587E+04
4	.4587E+04	0.	0.	0.	0.	-.4587E+04
5	.4587E+04	0.	0.	0.	0.	-.4587E+04
6	.4587E+04	0.	0.	0.	0.	-.4587E+04
7	.4587E+04	0.	0.	0.	0.	-.4587E+04
8	.4587E+04	0.	0.	0.	0.	-.4587E+04
9	.4587E+04	0.	0.	0.	0.	-.4587E+04
10	.4587E+04	0.	0.	0.	0.	-.4587E+04
11	.4587E+04	0.	0.	0.	0.	-.4587E+04
12	.4587E+04	0.	0.	0.	0.	-.4587E+04
13	.4587E+04	0.	0.	0.	0.	-.4587E+04
14	.4586E+04	0.	0.	0.	0.	-.4586E+04
15	.4585E+04	0.	0.	0.	0.	-.4585E+04
16	.4584E+04	0.	0.	0.	0.	-.4584E+04
17	.4583E+04	0.	0.	0.	0.	-.4583E+04
18	.4582E+04	0.	0.	0.	0.	-.4582E+04
19	.4581E+04	0.	0.	0.	0.	-.4581E+04
20	.4580E+04	0.	0.	0.	0.	-.4580E+04
21	.4579E+04	0.	0.	0.	0.	-.4579E+04
22	.4578E+04	0.	0.	0.	0.	-.4578E+04
23	.4577E+04	0.	0.	0.	0.	-.4577E+04

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
   4       1                                                -.2245E-03  .2164E-06  -.2543E-18  -.1529E-21  -.2953E-18  0.
 1  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 2  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 3  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 4  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 5  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 6  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 7  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 8  .6735E+04  0.      0.      0.      0.                   -.6735E+04
 9  .6735E+04  0.      0.      0.      0.                   -.6735E+04
10  .6735E+04  0.      0.      0.      0.                   -.6735E+04
11  .6735E+04  0.      0.      0.      0.                   -.6735E+04
12  .6735E+04  0.      0.      0.      0.                   -.6735E+04
13  .6735E+04  0.      0.      0.      0.                   -.6735E+04
14  .6738E+04  0.      0.      0.      0.                   -.6738E+04
15  .6740E+04  0.      0.      0.      0.                   -.6740E+04
16  .6742E+04  0.      0.      0.      0.                   -.6742E+04
17  .6744E+04  0.      0.      0.      0.                   -.6744E+04
18  .6746E+04  0.      0.      0.      0.                   -.6746E+04
19  .6749E+04  0.      0.      0.      0.                   -.6749E+04
20  .6751E+04  0.      0.      0.      0.                   -.6751E+04
21  .6753E+04  0.      0.      0.      0.                   -.6753E+04
22  .6755E+04  0.      0.      0.      0.                   -.6755E+04
23  .6757E+04  0.      0.      0.      0.                   -.6757E+04

   4       2                                                -.2168E-03  .4928E-07  -.1592E-18  -.1249E-21  -.2939E-18  0.
 1  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 2  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 3  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 4  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 5  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 6  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 7  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 8  .6503E+04  0.      0.      0.      0.                   -.6503E+04
 9  .6503E+04  0.      0.      0.      0.                   -.6503E+04
10  .6503E+04  0.      0.      0.      0.                   -.6503E+04
11  .6503E+04  0.      0.      0.      0.                   -.6503E+04
12  .6503E+04  0.      0.      0.      0.                   -.6503E+04
13  .6503E+04  0.      0.      0.      0.                   -.6503E+04
14  .6503E+04  0.      0.      0.      0.                   -.6503E+04
15  .6504E+04  0.      0.      0.      0.                   -.6504E+04
16  .6504E+04  0.      0.      0.      0.                   -.6504E+04
17  .6505E+04  0.      0.      0.      0.                   -.6505E+04
18  .6505E+04  0.      0.      0.      0.                   -.6505E+04
19  .6506E+04  0.      0.      0.      0.                   -.6506E+04
20  .6506E+04  0.      0.      0.      0.                   -.6506E+04
21  .6507E+04  0.      0.      0.      0.                   -.6507E+04
22  .6507E+04  0.      0.      0.      0.                   -.6507E+04
23  .6508E+04  0.      0.      0.      0.                   -.6508E+04
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
    4      3                                                        -.2140E-03  -.1422E-06  0.          0.          -.2990E-18  0.
 1   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 2   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 3   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 4   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 5   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 6   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 7   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 8   .6420E+04  0.         0.         0.         0.                 -.6420E+04
 9   .6420E+04  0.         0.         0.         0.                 -.6420E+04
10   .6420E+04  0.         0.         0.         0.                 -.6420E+04
11   .6420E+04  0.         0.         0.         0.                 -.6420E+04
12   .6420E+04  0.         0.         0.         0.                 -.6420E+04
13   .6420E+04  0.         0.         0.         0.                 -.6420E+04
14   .6419E+04  0.         0.         0.         0.                 -.6419E+04
15   .6418E+04  0.         0.         0.         0.                 -.6418E+04
16   .6416E+04  0.         0.         0.         0.                 -.6416E+04
17   .6415E+04  0.         0.         0.         0.                 -.6415E+04
18   .6413E+04  0.         0.         0.         0.                 -.6413E+04
19   .6412E+04  0.         0.         0.         0.                 -.6412E+04
20   .6410E+04  0.         0.         0.         0.                 -.6410E+04
21   .6409E+04  0.         0.         0.         0.                 -.6409E+04
22   .6407E+04  0.         0.         0.         0.                 -.6407E+04
23   .6406E+04  0.         0.         0.         0.                 -.6406E+04

    4      4                                                        -.2168E-03   .4928E-07   .1592E-18   .1077E-21  -.2934E-18  0.
 1   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 2   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 3   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 4   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 5   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 6   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 7   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 8   .6503E+04  0.         0.         0.         0.                 -.6503E+04
 9   .6503E+04  0.         0.         0.         0.                 -.6503E+04
10   .6503E+04  0.         0.         0.         0.                 -.6503E+04
11   .6503E+04  0.         0.         0.         0.                 -.6503E+04
12   .6503E+04  0.         0.         0.         0.                 -.6503E+04
13   .6503E+04  0.         0.         0.         0.                 -.6503E+04
14   .6503E+04  0.         0.         0.         0.                 -.6503E+04
15   .6504E+04  0.         0.         0.         0.                 -.6504E+04
16   .6504E+04  0.         0.         0.         0.                 -.6504E+04
17   .6505E+04  0.         0.         0.         0.                 -.6505E+04
18   .6505E+04  0.         0.         0.         0.                 -.6505E+04
19   .6506E+04  0.         0.         0.         0.                 -.6506E+04
20   .6506E+04  0.         0.         0.         0.                 -.6506E+04
21   .6507E+04  0.         0.         0.         0.                 -.6507E+04
22   .6507E+04  0.         0.         0.         0.                 -.6507E+04
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

23	.6508E+04	0.	0.	0.	0.	-.6508E+04					
	4	5				-.2245E-03	.2164E-06	.2543E-18	.2981E-22	-.2956E-18	0.
1	.6735E+04	0.	0.	0.	0.	-.6735E+04					
2	.6735E+04	0.	0.	0.	0.	-.6735E+04					
3	.6735E+04	0.	0.	0.	0.	-.6735E+04					
4	.6735E+04	0.	0.	0.	0.	-.6735E+04					
5	.6735E+04	0.	0.	0.	0.	-.6735E+04					
6	.6735E+04	0.	0.	0.	0.	-.6735E+04					
7	.6735E+04	0.	0.	0.	0.	-.6735E+04					
8	.6735E+04	0.	0.	0.	0.	-.6735E+04					
9	.6735E+04	0.	0.	0.	0.	-.6735E+04					
10	.6735E+04	0.	0.	0.	0.	-.6735E+04					
11	.6735E+04	0.	0.	0.	0.	-.6735E+04					
12	.6735E+04	0.	0.	0.	0.	-.6735E+04					
13	.6735E+04	0.	0.	0.	0.	-.6735E+04					
14	.6738E+04	0.	0.	0.	0.	-.6738E+04					
15	.6740E+04	0.	0.	0.	0.	-.6740E+04					
16	.6742E+04	0.	0.	0.	0.	-.6742E+04					
17	.6744E+04	0.	0.	0.	0.	-.6744E+04					
18	.6746E+04	0.	0.	0.	0.	-.6746E+04					
19	.6749E+04	0.	0.	0.	0.	-.6749E+04					
20	.6751E+04	0.	0.	0.	0.	-.6751E+04					
21	.6753E+04	0.	0.	0.	0.	-.6753E+04					
22	.6755E+04	0.	0.	0.	0.	-.6755E+04					
23	.6757E+04	0.	0.	0.	0.	-.6757E+04					

NODAL POINT DATA

INCREMENTAL DISPLACEMENTS

1	0.	0.	0.	0.	0.	0.	.40490E-02	0.	-.15942E-03
2	0.	0.	0.	0.	0.	0.	.40498E-02	0.	-.15942E-03
3	-.82390E-02	0.	-.13595E-02	0.	-.14729E-03	0.	.32126E-02	0.	-.11442E-03
4	0.	.14729E-03	0.	-.82390E-02	0.	-.13595E-02	.32126E-02	0.	-.11442E-03
5	-.12641E-01	0.	-.64978E-04	0.	-.21427E-03	0.	.21075E-02	0.	-.95246E-04

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

6	0.	.21427E-03	0.	-.12641E-01	0.	-.64978E-04	.21075E-02	0.	-.95246E-04
7	-.82390E-02	0.	0.	-.15662E-03	.32126E-02	0.	-.13595E-02	-.92157E-18	0.
8	0.	.15662E-03	-.82390E-02	0.	.32126E-02	0.	-.13595E-02	-.92157E-18	0.
9	-.12641E-01	0.	0.	-.22784E-03	.21075E-02	0.	-.64978E-04	-.29477E-18	0.
10	0.	.22784E-03	-.12641E-01	0.	.21075E-02	0.	-.64978E-0-	-.29477E-18	0.

TOTAL DISPLACEMENTS

1	0.	0.	0.	0.	0.	0.	.40490E-02	0.	-.15942E-03
2	0.	0.	0.	0.	0.	0.	.40490E-02	0.	-.15942E-03
3	-.82390E-02	0.	-.13595E-02	0.	-.14729E-03	0.	.32126E-02	0.	-.11442E-03
4	0.	.14729E-03	0.	-.82390E-02	0.	-.13595E-02	.32126E-02	0.	-.11442E-03
5	-.12641E-01	0.	-.64978E-04	0.	-.21427E-03	0.	.21075E-02	0.	-.95246E-04
6	0.	.21427E-03	0.	-.12641E-01	0.	-.64978E-04	.21075E-02	0.	-.95246E-04
7	-.82390E-02	0.	0.	-.15662E-03	.32126E-02	0.	-.13595E-02	-.92157E-18	0.
8	0.	.15662E-03	-.82390E-02	0.	.32126E-02	0.	-.13595E-02	-.92157E-18	0.
9	-.12641E-01	0.	0.	-.22784E-03	.21075E-02	0.	-.64978E-0-	-.29477E-18	0.
10	0.	.22784E-03	-.12641E-01	0.	.21075E-02	0.	-.64978E-0-	-.29477E-18	0.

LOAD TYPE 1 CURRENT MAGNITUDE .1000000E+03

LOAD TYPE 2 CURRENT MAGNITUDE .1000000E+03

CURRENT LOADS ARE 0.0000 TIMES DATA LOADS

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
            CONTINUE

                              PRINT EVERY    1  INCREMENTS
CPU IN:      34.887, CPU OUT:      38.039, CPU TOTAL:       3.152 OSCINC



RESULTS FOR SUBSTRUCTURE NO    2


    2      0      0

SOLUTION SCALED BY  .100E+01  TO CAUSE FIRST YIELD IN ELEMENT    1  IF SCALING WAS REQUESTED



                                          E L E M E N T   D A T A
                    I N V A R I A N T S                                      C O M P O N E N T S


ELEMENT    POINT                                                               INCREMENTAL STRAIN COMPONENTS
 NUMBER    NUMBER                                                   NO.1        NO.2        NO.3        NO.4        NO.5        NO

LYR. TOTAL        TOTAL       TOTAL       TOTAL       TOTAL
NO.  EQUIV.       MEAN        EQUIV.      EQUIV.                                      TOTAL STRESS COMPONENTS
   J2 TENSILE     NORMAL      PLASTIC     CREEP      TEMPERATURE
     STRESS       STRESS      STRAIN      STRAIN                    NO.1        NO.2        NO.3        NO.4        NO.5        NO

    1          1                                                -.2057E-03  -.9508E-04   .6198E-05  -.3510E-05  -.2817E-04  -.4167
 1   .7088E+04  0.          0.          0.          0.          -.7996E+04  -.5505E+04   .7087E+02
 2   .7058E+04  0.          0.          0.          0.          -.7972E+04  -.5447E+04   .7117E+02
 3   .7029E+04  0.          0.          0.          0.          -.7949E+04  -.5389E+04   .7146E+02
 4   .6999E+04  0.          0.          0.          0.          -.7925E+04  -.5331E+04   .7175E+02
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
  5  .6970E+04  0.        0.        0.        0.          -.7901E+04  -.5273E+04   .7204E+02
  6  .6941E+04  0.        0.        0.        0.          -.7877E+04  -.5215E+04   .7233E+02
  7  .6913E+04  0.        0.        0.        0.          -.7853E+04  -.5158E+04   .7263E+02
  8  .6884E+04  0.        0.        0.        0.          -.7830E+04  -.5100E+04   .7292E+02
  9  .6856E+04  0.        0.        0.        0.          -.7806E+04  -.5042E+04   .7321E+02
 10  .6829E+04  0.        0.        0.        0.          -.7782E+04  -.4984E+04   .7350E+02
 11  .6801E+04  0.        0.        0.        0.          -.7758E+04  -.4926E+04   .7379E+02

    1      2                                            -.2019E-03  -.9508E-04  -.8043E-17  -.3128E-05  -.2399E-04   .4101
  1  .6874E+04  0.        0.        0.        0.          -.7740E+04  -.5390E+04  -.9027E-10
  2  .6848E+04  0.        0.        0.        0.          -.7720E+04  -.5341E+04  -.9056E-10
  3  .6822E+04  0.        0.        0.        0.          -.7699E+04  -.5292E+04  -.9085E-10
  4  .6796E+04  0.        0.        0.        0.          -.7679E+04  -.5242E+04  -.9114E-10
  5  .6771E+04  0.        0.        0.        0.          -.7658E+04  -.5193E+04  -.9143E-10
  6  .6746E+04  0.        0.        0.        0.          -.7638E+04  -.5144E+04  -.9173E-10
  7  .6721E+04  0.        0.        0.        0.          -.7618E+04  -.5094E+04  -.9202E-10
  8  .6696E+04  0.        0.        0.        0.          -.7597E+04  -.5045E+04  -.9231E-10
  9  .6672E+04  0.        0.        0.        0.          -.7577E+04  -.4996E+04  -.9260E-10
 10  .6647E+04  0.        0.        0.        0.          -.7556E+04  -.4946E+04  -.9290E-10
 11  .6623E+04  0.        0.        0.        0.          -.7536E+04  -.4897E+04  -.9319E-10

    1      3                                            -.2057E-03  -.9508E-04  -.6198E-05  -.3510E-05  -.2817E-04   .4167
  1  .7088E+04  0.        0.        0.        0.          -.7996E+04  -.5505E+04  -.7087E+02
  2  .7058E+04  0.        0.        0.        0.          -.7972E+04  -.5447E+04  -.7117E+02
  3  .7029E+04  0.        0.        0.        0.          -.7949E+04  -.5389E+04  -.7146E+02
  4  .6999E+04  0.        0.        0.        0.          -.7925E+04  -.5331E+04  -.7175E+02
  5  .6970E+04  0.        0.        0.        0.          -.7901E+04  -.5273E+04  -.7204E+02
  6  .6941E+04  0.        0.        0.        0.          -.7877E+04  -.5215E+04  -.7233E+02
  7  .6913E+04  0.        0.        0.        0.          -.7853E+04  -.5158E+04  -.7263E+02
  8  .6884E+04  0.        0.        0.        0.          -.7830E+04  -.5100E+04  -.7292E+02
  9  .6856E+04  0.        0.        0.        0.          -.7806E+04  -.5042E+04  -.7321E+02
 10  .6829E+04  0.        0.        0.        0.          -.7782E+04  -.4984E+04  -.7350E+02
 11  .6801E+04  0.        0.        0.        0.          -.7758E+04  -.4926E+04  -.7379E+02

    1      4                                            -.2037E-03  -.9509E-04  -.1782E-05  -.3493E-05  -.5941E-05   .5026
  1  .6940E+04  0.        0.        0.        0.          -.7864E+04  -.5265E+04  -.2062E+02
  2  .6929E+04  0.        0.        0.        0.          -.7854E+04  -.5251E+04  -.2066E+02
  3  .6919E+04  0.        0.        0.        0.          -.7843E+04  -.5238E+04  -.2069E+02
  4  .6908E+04  0.        0.        0.        0.          -.7833E+04  -.5224E+04  -.2073E+02
  5  .6897E+04  0.        0.        0.        0.          -.7822E+04  -.5210E+04  -.2076E+02
  6  .6887E+04  0.        0.        0.        0.          -.7811E+04  -.5196E+04  -.2080E+02
  7  .6876E+04  0.        0.        0.        0.          -.7801E+04  -.5182E+04  -.2083E+02
  8  .6866E+04  0.        0.        0.        0.          -.7790E+04  -.5168E+04  -.2087E+02
  9  .6855E+04  0.        0.        0.        0.          -.7780E+04  -.5154E+04  -.2090E+02
 10  .6844E+04  0.        0.        0.        0.          -.7769E+04  -.5141E+04  -.2094E+02
 11  .6834E+04  0.        0.        0.        0.          -.7758E+04  -.5127E+04  -.2098E+02

    1      5                                            -.2009E-03  -.9509E-04  -.1264E-16  -.3091E-05  -.4469E-05  -.6715
  1  .6762E+04  0.        0.        0.        0.          -.7647E+04  -.5186E+04  -.2016E-09
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

2	.6753E+04	0.	0.	0.	0.	-.7639E+04	-.5176E+04	-.2010E-09			
3	.6744E+04	0.	0.	0.	0.	-.7630E+04	-.5165E+04	-.2005E-09			
4	.6735E+04	0.	0.	0.	0.	-.7621E+04	-.5155E+04	-.1999E-09			
5	.6727E+04	0.	0.	0.	0.	-.7612E+04	-.5144E+04	-.1994E-09			
6	.6718E+04	0.	0.	0.	0.	-.7603E+04	-.5134E+04	-.1988E-09			
7	.6709E+04	0.	0.	0.	0.	-.7595E+04	-.5123E+04	-.1983E-09			
8	.6701E+04	0.	0.	0.	0.	-.7586E+04	-.5113E+04	-.1978E-09			
9	.6692E+04	0.	0.	0.	0.	-.7577E+04	-.5102E+04	-.1972E-09			
10	.6684E+04	0.	0.	0.	0.	-.7568E+04	-.5091E+04	-.1967E-09			
11	.6675E+04	0.	0.	0.	0.	-.7560E+04	-.5081E+04	-.1961E-09			
1	6					-.2037E-03	-.9509E-04	.1732E-05	-.3493E-05	-.5941E-05	-.5026
1	.6940E+04	0.	0.	0.	0.	-.7864E+04	-.5265E+04	.2062E+02			
2	.6929E+04	0.	0.	0.	0.	-.7854E+04	-.5251E+04	.2066E+02			
3	.6919E+04	0.	0.	0.	0.	-.7843E+04	-.5238E+04	.2069E+02			
4	.6908E+04	0.	0.	0.	0.	-.7833E+04	-.5224E+04	.2073E+02			
5	.6897E+04	0.	0.	0.	0.	-.7822E+04	-.5210E+04	.2076E+02			
6	.6887E+04	0.	0.	0.	0.	-.7811E+04	-.5196E+04	.2080E+02			
7	.6876E+04	0.	0.	0.	0.	-.7801E+04	-.5182E+04	.2083E+02			
8	.6866E+04	0.	0.	0.	0.	-.7790E+04	-.5168E+04	.2087E+02			
9	.6855E+04	0.	0.	0.	0.	-.7780E+04	-.5154E+04	.2090E+02			
10	.6844E+04	0.	0.	0.	0.	-.7769E+04	-.5141E+04	.2094E+02			
11	.6834E+04	0.	0.	0.	0.	-.7758E+04	-.5127E+04	.2098E+02			
1	7					-.2009E-03	-.9601E-04	-.1966E-05	-.3431E-05	.1629E-04	.9929
1	.6785E+04	0.	0.	0.	0.	-.7713E+04	-.5048E+04	-.2259E+02			
2	.6793E+04	0.	0.	0.	0.	-.7716E+04	-.5078E+04	-.2266E+02			
3	.6800E+04	0.	0.	0.	0.	-.7719E+04	-.5108E+04	-.2273E+02			
4	.6808E+04	0.	0.	0.	0.	-.7722E+04	-.5138E+04	-.2280E+02			
5	.6816E+04	0.	0.	0.	0.	-.7724E+04	-.5168E+04	-.2287E+02			
6	.6824E+04	0.	0.	0.	0.	-.7727E+04	-.5198E+04	-.2294E+02			
7	.6832E+04	0.	0.	0.	0.	-.7730E+04	-.5229E+04	-.2301E+02			
8	.6840E+04	0.	0.	0.	0.	-.7732E+04	-.5259E+04	-.2308E+02			
9	.6848E+04	0.	0.	0.	0.	-.7735E+04	-.5289E+04	-.2315E+02			
10	.6856E+04	0.	0.	0.	0.	-.7738E+04	-.5319E+04	-.2322E+02			
11	.6865E+04	0.	0.	0.	0.	-.7741E+04	-.5349E+04	-.2329E+02			
1	8					-.1974E-03	-.9601E-04	-.7190E-17	-.3055E-05	.1517E-04	-.3798
1	.6598E+04	0.	0.	0.	0.	-.7481E+04	-.4988E+04	-.1000E-09			
2	.6606E+04	0.	0.	0.	0.	-.7484E+04	-.5016E+04	-.9980E-10			
3	.6613E+04	0.	0.	0.	0.	-.7487E+04	-.5045E+04	-.9957E-10			
4	.6621E+04	0.	0.	0.	0.	-.7490E+04	-.5073E+04	-.9935E-10			
5	.6629E+04	0.	0.	0.	0.	-.7493E+04	-.5101E+04	-.9912E-10			
6	.6637E+04	0.	0.	0.	0.	-.7496E+04	-.5129E+04	-.9890E-10			
7	.6645E+04	0.	0.	0.	0.	-.7499E+04	-.5157E+04	-.9867E-10			
8	.6653E+04	0.	0.	0.	0.	-.7502E+04	-.5186E+04	-.9845E-10			
9	.6662E+04	0.	0.	0.	0.	-.7505E+04	-.5214E+04	-.9822E-10			
10	.6670E+04	0.	0.	0.	0.	-.7508E+04	-.5242E+04	-.9800E-10			
11	.6678E+04	0.	0.	0.	0.	-.7511E+04	-.5270E+04	-.9777E-10			

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

	1	9				-.2009E-03	-.9601E-04	.1966E-05	-.3431E-05	.1629E-06	-.9929
1	.6785E+04	0.	0.	0.	0.	-.7713E+04	-.5048E+04	.2259E+02			
2	.6793E+04	0.	0.	0.	0.	-.7716E+04	-.5078E+04	.2266E+02			
3	.6800E+04	0.	0.	0.	0.	-.7719E+04	-.5108E+04	.2273E+02			
4	.6808E+04	0.	0.	0.	0.	-.7722E+04	-.5138E+04	.2280E+02			
5	.6816E+04	0.	0.	0.	0.	-.7724E+04	-.5168E+04	.2287E+02			
6	.6824E+04	0.	0.	0.	0.	-.7727E+04	-.5198E+04	.2294E+02			
7	.6832E+04	0.	0.	0.	0.	-.7730E+04	-.5229E+04	.2301E+02			
8	.6840E+04	0.	0.	0.	0.	-.7732E+04	-.5259E+04	.2308E+02			
9	.6848E+04	0.	0.	0.	0.	-.7735E+04	-.5289E+04	.2315E+02			
10	.6856E+04	0.	0.	0.	0.	-.7738E+04	-.5319E+04	.2322E+02			
11	.6865E+04	0.	0.	0.	0.	-.7741E+04	-.5349E+04	.2329E+02			
	2	1				-.2007E-03	-.9636E-04	-.3640E-06	-.3423E-05	.8583E-06	.2298
1	.6845E+04	0.	0.	0.	0.	-.7753E+04	-.5209E+04	-.4168E+01			
2	.6841E+04	0.	0.	0.	0.	-.7747E+04	-.5209E+04	-.4184E+01			
3	.6836E+04	0.	0.	0.	0.	-.7740E+04	-.5208E+04	-.4200E+01			
4	.6831E+04	0.	0.	0.	0.	-.7734E+04	-.5208E+04	-.4216E+01			
5	.6826E+04	0.	0.	0.	0.	-.7728E+04	-.5208E+04	-.4233E+01			
6	.6821E+04	0.	0.	0.	0.	-.7721E+04	-.5207E+04	-.4249E+01			
7	.6816E+04	0.	0.	0.	0.	-.7715E+04	-.5207E+04	-.4265E+01			
8	.6811E+04	0.	0.	0.	0.	-.7708E+04	-.5206E+04	-.4281E+01			
9	.6806E+04	0.	0.	0.	0.	-.7702E+04	-.5206E+04	-.4297E+01			
10	.6801E+04	0.	0.	0.	0.	-.7695E+04	-.5206E+04	-.4313E+01			
11	.6797E+04	0.	0.	0.	0.	-.7689E+04	-.5205E+04	-.4329E+01			
	2	2				-.1969E-03	-.9636E-04	-.4744E-17	-.3052E-05	.6332E-06	.4846
1	.6651E+04	0.	0.	0.	0.	-.7513E+04	-.5139E+04	-.3727E-10			
2	.6647E+04	0.	0.	0.	0.	-.7507E+04	-.5138E+04	-.4064E-10			
3	.6643E+04	0.	0.	0.	0.	-.7501E+04	-.5138E+04	-.4400E-10			
4	.6638E+04	0.	0.	0.	0.	-.7495E+04	-.5137E+04	-.4737E-10			
5	.6634E+04	0.	0.	0.	0.	-.7490E+04	-.5137E+04	-.5073E-10			
6	.6630E+04	0.	0.	0.	0.	-.7484E+04	-.5136E+04	-.5410E-10			
7	.6625E+04	0.	0.	0.	0.	-.7478E+04	-.5135E+04	-.5747E-10			
8	.6621E+04	0.	0.	0.	0.	-.7473E+04	-.5135E+04	-.6083E-10			
9	.6617E+04	0.	0.	0.	0.	-.7467E+04	-.5134E+04	-.6420E-10			
10	.6612E+04	0.	0.	0.	0.	-.7461E+04	-.5134E+04	-.6756E-10			
11	.6608E+04	0.	0.	0.	0.	-.7456E+04	-.5133E+04	-.7093E-10			
	2	3				-.2007E-03	-.9636E-04	.3640E-06	-.3423E-05	.8583E-06	-.2298
1	.6845E+04	0.	0.	0.	0.	-.7753E+04	-.5209E+04	.4168E+01			
2	.6841E+04	0.	0.	0.	0.	-.7747E+04	-.5209E+04	.4184E+01			
3	.6836E+04	0.	0.	0.	0.	-.7740E+04	-.5208E+04	.4200E+01			
4	.6831E+04	0.	0.	0.	0.	-.7734E+04	-.5208E+04	.4216E+01			
5	.6826E+04	0.	0.	0.	0.	-.7728E+04	-.5208E+04	.4233E+01			
6	.6821E+04	0.	0.	0.	0.	-.7721E+04	-.5207E+04	.4249E+01			
7	.6816E+04	0.	0.	0.	0.	-.7715E+04	-.5207E+04	.4265E+01			
8	.6811E+04	0.	0.	0.	0.	-.7708E+04	-.5206E+04	.4281E+01			

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
  9   .6805E+04  0.          0.          0.          0.          -.7702E+04  -.5206E+04   .4297E+01
 10   .6801E+04  0.          0.          0.          0.          -.7695E+04  -.5206E+04   .4313E+01
 11   .6797E+04  0.          0.          0.          0.          -.7689E+04  -.5205E+04   .4329E+01

    2        4                                                   -.2006E-03  -.9619E-04   .4279E-07  -.3421E-05   .3126E-06  -.2781
  1   .6845E+04  0.          0.          0.          0.          -.7752E+04  -.5209E+04   .4897E+00
  2   .6839E+04  0.          0.          0.          0.          -.7745E+04  -.5207E+04   .4916E+00
  3   .6834E+04  0.          0.          0.          0.          -.7739E+04  -.5206E+04   .4936E+00
  4   .6828E+04  0.          0.          0.          0.          -.7732E+04  -.5204E+04   .4955E+00
  5   .6823E+04  0.          0.          0.          0.          -.7725E+04  -.5203E+04   .4974E+00
  6   .6818E+04  0.          0.          0.          0.          -.7719E+04  -.5201E+04   .4994E+00
  7   .6812E+04  0.          0.          0.          0.          -.7712E+04  -.5200E+04   .5013E+00
  8   .6807E+04  0.          0.          0.          0.          -.7705E+04  -.5198E+04   .5033E+00
  9   .6802E+04  0.          0.          0.          0.          -.7698E+04  -.5197E+04   .5052E+00
 10   .6796E+04  0.          0.          0.          0.          -.7692E+04  -.5195E+04   .5072E+00
 11   .6791E+04  0.          0.          0.          0.          -.7685E+04  -.5194E+04   .5091E+00

    2        5                                                   -.1968E-03  -.9619E-04  -.1209E-16  -.3052E-05   .2320E-06   .1109
  1   .6649E+04  0.          0.          0.          0.          -.7509E+04  -.5136E+04  -.1535E-09
  2   .6644E+04  0.          0.          0.          0.          -.7503E+04  -.5135E+04  -.1512E-09
  3   .6639E+04  0.          0.          0.          0.          -.7498E+04  -.5134E+04  -.1689E-09
  4   .6634E+04  0.          0.          0.          0.          -.7492E+04  -.5132E+04  -.1766E-09
  5   .6630E+04  0.          0.          0.          0.          -.7486E+04  -.5131E+04  -.1842E-09
  6   .6625E+04  0.          0.          0.          0.          -.7480E+04  -.5130E+04  -.1919E-09
  7   .6620E+04  0.          0.          0.          0.          -.7474E+04  -.5128E+04  -.1996E-09
  8   .6616E+04  0.          0.          0.          0.          -.7468E+04  -.5127E+04  -.2072E-09
  9   .6611E+04  0.          0.          0.          0.          -.7462E+04  -.5125E+04  -.2149E-09
 10   .6606E+04  0.          0.          0.          0.          -.7456E+04  -.5124E+04  -.2226E-09
 11   .6602E+04  0.          0.          0.          0.          -.7450E+04  -.5123E+04  -.2302E-09

    2        6                                                   -.2006E-03  -.9619E-04  -.4279E-07  -.3421E-05   .3126E-06   .2781
  1   .6845E+04  0.          0.          0.          0.          -.7752E+04  -.5209E+04  -.4897E+00
  2   .6839E+04  0.          0.          0.          0.          -.7745E+04  -.5207E+04  -.4916E+00
  3   .6834E+04  0.          0.          0.          0.          -.7739E+04  -.5206E+04  -.4936E+00
  4   .6828E+04  0.          0.          0.          0.          -.7732E+04  -.5204E+04  -.4955E+00
  5   .6823E+04  0.          0.          0.          0.          -.7725E+04  -.5203E+04  -.4974E+00
  6   .6818E+04  0.          0.          0.          0.          -.7719E+04  -.5201E+04  -.4994E+00
  7   .6812E+04  0.          0.          0.          0.          -.7712E+04  -.5200E+04  -.5013E+00
  8   .6807E+04  0.          0.          0.          0.          -.7705E+04  -.5198E+04  -.5033E+00
  9   .6802E+04  0.          0.          0.          0.          -.7698E+04  -.5197E+04  -.5052E+00
 10   .6796E+04  0.          0.          0.          0.          -.7692E+04  -.5195E+04  -.5072E+00
 11   .6791E+04  0.          0.          0.          0.          -.7685E+04  -.5194E+04  -.5091E+00

    2        7                                                   -.2006E-03  -.9624E-04   .6553E-07  -.3422E-05  -.2331E-06  -.4173
  1   .6848E+04  0.          0.          0.          0.          -.7755E+04  -.5216E+04   .7502E+00
  2   .6842E+04  0.          0.          0.          0.          -.7748E+04  -.5213E+04   .7531E+00
  3   .6836E+04  0.          0.          0.          0.          -.7741E+04  -.5211E+04   .7560E+00
  4   .6831E+04  0.          0.          0.          0.          -.7734E+04  -.5208E+04   .7589E+00
  5   .6825E+04  0.          0.          0.          0.          -.7727E+04  -.5206E+04   .7519E+00
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A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

6	.6819E+04	0.	0.	0.	0.	-.7719E+04	-.5203E+04	.7648E+00			
7	.6813E+04	0.	0.	0.	0.	-.7712E+04	-.5200E+04	.7577E+00			
8	.6807E+04	0.	0.	0.	0.	-.7705E+04	-.5198E+04	.7706E+00			
9	.6801E+04	0.	0.	0.	0.	-.7698E+04	-.5195E+04	.7735E+00			
10	.6796E+04	0.	0.	0.	0.	-.7691E+04	-.5193E+04	.7765E+00			
11	.6790E+04	0.	0.	0.	0.	-.7684E+04	-.5190E+04	.7794E+00			
2	8					-.1969E-03	-.9624E-04	-.4134E-17	-.3052E-05	-.1692E-05	.4327
1	.6652E+04	0.	0.	0.	0.	-.7513E+04	-.5143E+04	-.6588E-10			
2	.6647E+04	0.	0.	0.	0.	-.7507E+04	-.5140E+04	-.6887E-10			
3	.6642E+04	0.	0.	0.	0.	-.7500E+04	-.5138E+04	-.7185E-10			
4	.6637E+04	0.	0.	0.	0.	-.7494E+04	-.5136E+04	-.7483E-10			
5	.6632E+04	0.	0.	0.	0.	-.7488E+04	-.5134E+04	-.7782E-10			
6	.6627E+04	0.	0.	0.	0.	-.7482E+04	-.5132E+04	-.8080E-10			
7	.6622E+04	0.	0.	0.	0.	-.7476E+04	-.5130E+04	-.8378E-10			
8	.6617E+04	0.	0.	0.	0.	-.7470E+04	-.5127E+04	-.8677E-10			
9	.6612E+04	0.	0.	0.	0.	-.7463E+04	-.5125E+04	-.8975E-10			
10	.6607E+04	0.	0.	0.	0.	-.7457E+04	-.5123E+04	-.9273E-10			
11	.6602E+04	0.	0.	0.	0.	-.7451E+04	-.5121E+04	-.9572E-10			
2	9					-.2006E-03	-.9624E-04	-.6553E-07	-.3422E-05	-.2331E-06	.4173
1	.6848E+04	0.	0.	0.	0.	-.7755E+04	-.5216E+04	-.7502E+00			
2	.6842E+04	0.	0.	0.	0.	-.7748E+04	-.5213E+04	-.7531E+00			
3	.6836E+04	0.	0.	0.	0.	-.7741E+04	-.5211E+04	-.7560E+00			
4	.6831E+04	0.	0.	0.	0.	-.7734E+04	-.5208E+04	-.7589E+00			
5	.6825E+04	0.	0.	0.	0.	-.7727E+04	-.5206E+04	-.7519E+00			
6	.6819E+04	0.	0.	0.	0.	-.7719E+04	-.5203E+04	-.7548E+00			
7	.6813E+04	0.	0.	0.	0.	-.7712E+04	-.5200E+04	-.7677E+00			
8	.6807E+04	0.	0.	0.	0.	-.7705E+04	-.5198E+04	-.7706E+00			
9	.6801E+04	0.	0.	0.	0.	-.7698E+04	-.5195E+04	-.7735E+00			
10	.6796E+04	0.	0.	0.	0.	-.7691E+04	-.5193E+04	-.7765E+00			
11	.6790E+04	0.	0.	0.	0.	-.7684E+04	-.5190E+04	-.7794E+00			

E L E M E N T   D A T A

I N V A R I A N T S   C O M P O N E N T S

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

ELEMENT NUMBER	POINT NUMBER					INCREMENTAL STRAIN COMPONENTS NO.1	NO.2	NO.3	NO.4	NO.5	NO
LYR. NO.	TOTAL EQUIV. J2 TENSILE STRESS	TOTAL MEAN NORMAL STRESS	TOTAL EQUIV. PLASTIC STRAIN	TOTAL EQUIV. CREEP STRAIN	TOTAL TEMPERATURE	TOTAL STRESS COMPONENTS NO.1	NO.2	NO.3	NO.4	NO.5	NO
3	1					-.2191E-03	.2439E-06	-.1423E-18	.2331E-24	-.1262E-18	0.
1	.6573E+04	0.	0.	0.	0.	-.6573E+04					
2	.6573E+04	0.	0.	0.	0.	-.6573E+04					
3	.6573E+04	0.	0.	0.	0.	-.6573E+04					
4	.6573E+04	0.	0.	0.	0.	-.6573E+04					
5	.6573E+04	0.	0.	0.	0.	-.6573E+04					
6	.6573E+04	0.	0.	0.	0.	-.6573E+04					
7	.6573E+04	0.	0.	0.	0.	-.6573E+04					
8	.6573E+04	0.	0.	0.	0.	-.6573E+04					
9	.6573E+04	0.	0.	0.	0.	-.6573E+04					
10	.6573E+04	0.	0.	0.	0.	-.6573E+04					
11	.6573E+04	0.	0.	0.	0.	-.6573E+04					
12	.6573E+04	0.	0.	0.	0.	-.6573E+04					
13	.6573E+04	0.	0.	0.	0.	-.6573E+04					
14	.6576E+04	0.	0.	0.	0.	-.6576E+04					
15	.6578E+04	0.	0.	0.	0.	-.6578E+04					
16	.6581E+04	0.	0.	0.	0.	-.6581E+04					
17	.6583E+04	0.	0.	0.	0.	-.6583E+04					
18	.6586E+04	0.	0.	0.	0.	-.6586E+04					
19	.6588E+04	0.	0.	0.	0.	-.6588E+04					
20	.6591E+04	0.	0.	0.	0.	-.6591E+04					
21	.6593E+04	0.	0.	0.	0.	-.6593E+04					
22	.6596E+04	0.	0.	0.	0.	-.6596E+04					
23	.6598E+04	0.	0.	0.	0.	-.6598E+04					
3	2					-.2123E-03	.4512E-07	-.8470E-19	-.4739E-24	-.1262E-18	0.
1	.6368E+04	0.	0.	0.	0.	-.6368E+04					
2	.6368E+04	0.	0.	0.	0.	-.6368E+04					
3	.6368E+04	0.	0.	0.	0.	-.6368E+04					
4	.6368E+04	0.	0.	0.	0.	-.6368E+04					
5	.6368E+04	0.	0.	0.	0.	-.6368E+04					
6	.6368E+04	0.	0.	0.	0.	-.6368E+04					
7	.6368E+04	0.	0.	0.	0.	-.6368E+04					
8	.6368E+04	0.	0.	0.	0.	-.6368E+04					
9	.6368E+04	0.	0.	0.	0.	-.6368E+04					
10	.6368E+04	0.	0.	0.	0.	-.6368E+04					
11	.6368E+04	0.	0.	0.	0.	-.6368E+04					
12	.6368E+04	0.	0.	0.	0.	-.6368E+04					
13	.6368E+04	0.	0.	0.	0.	-.6368E+04					
14	.6369E+04	0.	0.	0.	0.	-.6369E+04					
15	.6369E+04	0.	0.	0.	0.	-.6369E+04					

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

16	.6370E+04	0.	0.	0.	0.	-.6370E+04					
17	.6370E+04	0.	0.	0.	0.	-.6370E+04					
18	.6371E+04	0.	0.	0.	0.	-.6371E+04					
19	.6371E+04	0.	0.	0.	0.	-.6371E+04					
20	.6372E+04	0.	0.	0.	0.	-.6372E+04					
21	.6372E+04	0.	0.	0.	0.	-.6372E+04					
22	.6373E+04	0.	0.	0.	0.	-.6373E+04					
23	.6373E+04	0.	0.	0.	0.	-.6373E+04					
3	3					-.2101E-03	-.1630E-06	0.	0.	-.1262E-18	0.
1	.6303E+04	0.	0.	0.	0.	-.6303E+04					
2	.6303E+04	0.	0.	0.	0.	-.6303E+04					
3	.6303E+04	0.	0.	0.	0.	-.6303E+04					
4	.6303E+04	0.	0.	0.	0.	-.6303E+04					
5	.6303E+04	0.	0.	0.	0.	-.6303E+04					
6	.6303E+04	0.	0.	0.	0.	-.6303E+04					
7	.6303E+04	0.	0.	0.	0.	-.6303E+04					
8	.6303E+04	0.	0.	0.	0.	-.6303E+04					
9	.6303E+04	0.	0.	0.	0.	-.6303E+04					
10	.6303E+04	0.	0.	0.	0.	-.6303E+04					
11	.6303E+04	0.	0.	0.	0.	-.6303E+04					
12	.6303E+04	0.	0.	0.	0.	-.6303E+04					
13	.6303E+04	0.	0.	0.	0.	-.6303E+04					
14	.6301E+04	0.	0.	0.	0.	-.6301E+04					
15	.6299E+04	0.	0.	0.	0.	-.6299E+04					
16	.6298E+04	0.	0.	0.	0.	-.6298E+04					
17	.6296E+04	0.	0.	0.	0.	-.6296E+04					
18	.6295E+04	0.	0.	0.	0.	-.6295E+04					
19	.6293E+04	0.	0.	0.	0.	-.6293E+04					
20	.6291E+04	0.	0.	0.	0.	-.6291E+04					
21	.6290E+04	0.	0.	0.	0.	-.6290E+04					
22	.6288E+04	0.	0.	0.	0.	-.6288E+04					
23	.6286E+04	0.	0.	0.	0.	-.6286E+04					
3	4					-.2123E-03	.4512E-07	.8470E-19	.4648E-24	-.1262E-18	0.
1	.6368E+04	0.	0.	0.	0.	-.6368E+04					
2	.6368E+04	0.	0.	0.	0.	-.6368E+04					
3	.6368E+04	0.	0.	0.	0.	-.6368E+04					
4	.6368E+04	0.	0.	0.	0.	-.6368E+04					
5	.6368E+04	0.	0.	0.	0.	-.6368E+04					
6	.6368E+04	0.	0.	0.	0.	-.6368E+04					
7	.6368E+04	0.	0.	0.	0.	-.6368E+04					
8	.6368E+04	0.	0.	0.	0.	-.6368E+04					
9	.6368E+04	0.	0.	0.	0.	-.6368E+04					
10	.6368E+04	0.	0.	0.	0.	-.6368E+04					
11	.6368E+04	0.	0.	0.	0.	-.6368E+04					
12	.6368E+04	0.	0.	0.	0.	-.6368E+04					
13	.6368E+04	0.	0.	0.	0.	-.6368E+04					
14	.6369E+04	0.	0.	0.	0.	-.6369E+04					

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

15	.6369E+04	0.	0.	0.	0.	-.6369E+04					
16	.6370E+04	0.	0.	0.	0.	-.6370E+04					
17	.6370E+04	0.	0.	0.	0.	-.6370E+04					
18	.6371E+04	0.	0.	0.	0.	-.6371E+04					
19	.6371E+04	0.	0.	0.	0.	-.6371E+04					
20	.6372E+04	0.	0.	0.	0.	-.6372E+04					
21	.6372E+04	0.	0.	0.	0.	-.6372E+04					
22	.6373E+04	0.	0.	0.	0.	-.6373E+04					
23	.6373E+04	0.	0.	0.	0.	-.6373E+04					
3	5					-.2191E-03	.2439E-06	.1423E-18	-.6860E-23	-.1262E-18	0.
1	.6573E+04	0.	0.	0.	0.	-.6573E+04					
2	.6573E+04	0.	0.	0.	0.	-.6573E+04					
3	.6573E+04	0.	0.	0.	0.	-.6573E+04					
4	.6573E+04	0.	0.	0.	0.	-.6573E+04					
5	.6573E+04	0.	0.	0.	0.	-.6573E+04					
6	.6573E+04	0.	0.	0.	0.	-.6573E+04					
7	.6573E+04	0.	0.	0.	0.	-.6573E+04					
8	.6573E+04	0.	0.	0.	0.	-.6573E+04					
9	.6573E+04	0.	0.	0.	0.	-.6573E+04					
10	.6573E+04	0.	0.	0.	0.	-.6573E+04					
11	.6573E+04	0.	0.	0.	0.	-.6573E+04					
12	.6573E+04	0.	0.	0.	0.	-.6573E+04					
13	.6573E+04	0.	0.	0.	0.	-.6573E+04					
14	.6576E+04	0.	0.	0.	0.	-.6576E+04					
15	.6578E+04	0.	0.	0.	0.	-.6578E+04					
16	.6581E+04	0.	0.	0.	0.	-.6581E+04					
17	.6583E+04	0.	0.	0.	0.	-.6583E+04					
18	.6586E+04	0.	0.	0.	0.	-.6586E+04					
19	.6588E+04	0.	0.	0.	0.	-.6588E+04					
20	.6591E+04	0.	0.	0.	0.	-.6591E+04					
21	.6593E+04	0.	0.	0.	0.	-.6593E+04					
22	.6596E+04	0.	0.	0.	0.	-.6596E+04					
23	.6598E+04	0.	0.	0.	0.	-.6598E+04					
4	1					-.2191E-03	.2415E-06	0.	0.	0.	0.
1	.6573E+04	0.	0.	0.	0.	-.6573E+04					
2	.6573E+04	0.	0.	0.	0.	-.6573E+04					
3	.6573E+04	0.	0.	0.	0.	-.6573E+04					
4	.6573E+04	0.	0.	0.	0.	-.6573E+04					
5	.6573E+04	0.	0.	0.	0.	-.6573E+04					
6	.6573E+04	0.	0.	0.	0.	-.6573E+04					
7	.6573E+04	0.	0.	0.	0.	-.6573E+04					
8	.6575E+04	0.	0.	0.	0.	-.6575E+04					
9	.6578E+04	0.	0.	0.	0.	-.6578E+04					
10	.6580E+04	0.	0.	0.	0.	-.6580E+04					
11	.6583E+04	0.	0.	0.	0.	-.6583E+04					
12	.6585E+04	0.	0.	0.	0.	-.6585E+04					
13	.6587E+04	0.	0.	0.	0.	-.6587E+04					

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

14	.6590E+04	0.	0.	0.	0.	-.6590E+04					
15	.6592E+04	0.	0.	0.	0.	-.6592E+04					
16	.6595E+04	0.	0.	0.	0.	-.6595E+04					
17	.6597E+04	0.	0.	0.	0.	-.6597E+04					
4	2					-.2122E-03	.453-E-07	0.	0.	0.	0.
1	.6366E+04	0.	0.	0.	0.	-.6366E+04					
2	.6366E+04	0.	0.	0.	0.	-.6366E+04					
3	.6366E+04	0.	0.	0.	0.	-.6366E+04					
4	.6366E+04	0.	0.	0.	0.	-.6366E+04					
5	.6366E+04	0.	0.	0.	0.	-.6366E+04					
6	.6366E+04	0.	0.	0.	0.	-.6366E+04					
7	.6366E+04	0.	0.	0.	0.	-.6366E+04					
8	.6367E+04	0.	0.	0.	0.	-.6367E+04					
9	.6367E+04	0.	0.	0.	0.	-.6367E+04					
10	.6368E+04	0.	0.	0.	0.	-.6368E+04					
11	.6368E+04	0.	0.	0.	0.	-.6368E+04					
12	.6369E+04	0.	0.	0.	0.	-.6369E+04					
13	.6369E+04	0.	0.	0.	0.	-.6369E+04					
14	.6369E+04	0.	0.	0.	0.	-.6369E+04					
15	.6370E+04	0.	0.	0.	0.	-.6370E+04					
16	.6370E+04	0.	0.	0.	0.	-.6370E+04					
17	.6371E+04	0.	0.	0.	0.	-.6371E+04					
4	3					-.2100E-03	-.1611E-06	0.	0.	0.	0.
1	.6299E+04	0.	0.	0.	0.	-.6299E+04					
2	.6299E+04	0.	0.	0.	0.	-.6299E+04					
3	.6299E+04	0.	0.	0.	0.	-.6299E+04					
4	.6299E+04	0.	0.	0.	0.	-.6299E+04					
5	.6299E+04	0.	0.	0.	0.	-.6299E+04					
6	.6299E+04	0.	0.	0.	0.	-.6299E+04					
7	.6299E+04	0.	0.	0.	0.	-.6299E+04					
8	.6298E+04	0.	0.	0.	0.	-.6298E+04					
9	.6296E+04	0.	0.	0.	0.	-.6296E+04					
10	.6295E+04	0.	0.	0.	0.	-.6295E+04					
11	.6293E+04	0.	0.	0.	0.	-.6293E+04					
12	.6291E+04	0.	0.	0.	0.	-.6291E+04					
13	.6290E+04	0.	0.	0.	0.	-.6290E+04					
14	.6288E+04	0.	0.	0.	0.	-.6288E+04					
15	.6286E+04	0.	0.	0.	0.	-.6286E+04					
16	.6285E+04	0.	0.	0.	0.	-.6285E+04					
17	.6283E+04	0.	0.	0.	0.	-.6283E+04					
4	4					-.2122E-03	.4534E-07	0.	0.	0.	0.
1	.6366E+04	0.	0.	0.	0.	-.6366E+04					
2	.6366E+04	0.	0.	0.	0.	-.6366E+04					
3	.6366E+04	0.	0.	0.	0.	-.6366E+04					
4	.6366E+04	0.	0.	0.	0.	-.6366E+04					
5	.6366E+04	0.	0.	0.	0.	-.6366E+04					

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

6	.6366E+04	0.	0.	0.	0.	-.6366E+04
7	.6366E+04	0.	0.	0.	0.	-.6366E+04
8	.6367E+04	0.	0.	0.	0.	-.6367E+04
9	.6367E+04	0.	0.	0.	0.	-.6367E+04
10	.6368E+04	0.	0.	0.	0.	-.6368E+04
11	.6368E+04	0.	0.	0.	0.	-.6368E+04
12	.6369E+04	0.	0.	0.	0.	-.6369E+04
13	.6369E+04	0.	0.	0.	0.	-.6369E+04
14	.6369E+04	0.	0.	0.	0.	-.6369E+04
15	.6370E+04	0.	0.	0.	0.	-.6370E+04
16	.6370E+04	0.	0.	0.	0.	-.6370E+04
17	.6371E+04	0.	0.	0.	0.	-.6371E+04

4 5 -.2191E-03 .2415E-06 0. 0. 0. 0.

1	.6573E+04	0.	0.	0.	0.	-.6573E+04
2	.6573E+04	0.	0.	0.	0.	-.6573E+04
3	.6573E+04	0.	0.	0.	0.	-.6573E+04
4	.6573E+04	0.	0.	0.	0.	-.6573E+04
5	.6573E+04	0.	0.	0.	0.	-.6573E+04
6	.6573E+04	0.	0.	0.	0.	-.6573E+04
7	.6573E+04	0.	0.	0.	0.	-.6573E+04
8	.6575E+04	0.	0.	0.	0.	-.6575E+04
9	.6578E+04	0.	0.	0.	0.	-.6578E+04
10	.6580E+04	0.	0.	0.	0.	-.6580E+04
11	.6583E+04	0.	0.	0.	0.	-.6583E+04
12	.6585E+04	0.	0.	0.	0.	-.6585E+04
13	.6587E+04	0.	0.	0.	0.	-.6587E+04
14	.6590E+04	0.	0.	0.	0.	-.6590E+04
15	.6592E+04	0.	0.	0.	0.	-.6592E+04
16	.6595E+04	0.	0.	0.	0.	-.6595E+04
17	.6597E+04	0.	0.	0.	0.	-.6597E+04

NODAL POINT DATA

INCREMENTAL DISPLACEMENTS

1	-.12641E-01	0.	-.64978E-04	0.	-.21427E-03	0.	.21075E-02	0.	-.95246E-04
2	0.	.21427E-03	0.	-.12641E-01	0.	-.64978E-04	.21075E-02	0.	-.95246E-04

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

3	-.12387E-01	0.	.36091E-05	0.	-.20894E-03	0.	.10588E-02	0.	-.96452E-04
4	0.	.20894E-03	0.	-.12387E-01	0.	.36091E-05	.10588E-02	0.	-.96452E-04
5	-.12382E-01	0.	0.	0.	-.20893E-03	0.	0.	0.	-.96296E-04
6	0.	.20893E-03	0.	-.12382E-01	0.	0.	0.	0.	-.96296E-04
7	-.12387E-01	0.	0.	-.22217E-03	.10588E-02	0.	.36091E-05	-.12621E-18	0.
8	0.	.22217E-03	-.12387E-01	0.	.10588E-02	0.	.36091E-05	-.12621E-18	0.
9	-.12382E-01	0.	0.	-.22216E-03	0.	0.	0.	0.	0.
10	0.	.22216E-03	-.12382E-01	0.	0.	0.	0.	0.	0.

TOTAL DISPLACEMENTS

1	-.12641E-01	0.	-.64978E-04	0.	-.21427E-03	0.	.21075E-02	0.	-.95246E-04
2	0.	.21427E-03	0.	-.12641E-01	0.	-.64978E-04	.21075E-02	0.	-.95246E-04
3	-.12387E-01	0.	.36091E-05	0.	-.20894E-03	0.	.10588E-02	0.	-.96452E-04
4	0.	.20894E-03	0.	-.12387E-01	0.	.36091E-05	.10588E-02	0.	-.96452E-04
5	-.12382E-01	0.	0.	0.	-.20893E-03	0.	0.	0.	-.96296E-04
6	0.	.20893E-03	0.	-.12382E-01	0.	0.	0.	0.	-.96296E-04
7	-.12387E-01	0.	0.	-.22217E-03	.10588E-02	0.	.36091E-05	-.12621E-18	0.
8	0.	.22217E-03	-.12387E-01	0.	.10588E-02	0.	.36091E-05	-.12521E-18	0.
9	-.12382E-01	0.	0.	-.22216E-03	0.	0.	0.	0.	0.
10	0.	.22216E-03	-.12382E-01	0.	0.	0.	0.	0.	0.

LOAD TYPE 1 CURRENT MAGNITUDE .1000000E+03

LOAD TYPE 2 CURRENT MAGNITUDE .1000000E+03

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
CURRENT LOADS ARE       0.0C00   TIMES DATA LOADS

                                              END OF INCREMENT   3

                                              START INCREMENT   4

          CONTINUE

                                   PRINT EVERY   1  INCREMENTS

CPU IN:      38.475, CPU OUT:      41.514, CPU TOTAL:       3.039 OSCINC

  -1     0
 MONITOR SUMMARY - DATE: 08/17/79 TIME: 17.35.18.
```

	MODULE	COUNT	CPU SECS	PCT	PP SECS	PCT	IO SECS	PCT	CLOCK	PCT
1	MARC	1	.457	1.12	1.134	4.63	.210	1.10	2.	2.33
2	CONTRA	2	.931	2.28	4.378	17.88	2.898	15.18	9.	10.47
3	OAREAD	2	2.213	5.43	1.953	7.98	1.657	8.68	8.	9.30
4	OPRESS	2	.569	1.40	.231	.95	.139	.73	1.	1.16
5	OASEMB	2	10.954	26.83	.896	3.66	.745	3.90	12.	13.95
6	OSOLV1	2	7.427	18.23	6.994	28.57	6.642	34.77	19.	22.09
7	CONTRB	1	.217	.53	1.131	4.62	1.086	5.69	2.	2.33
8	CONTRC	4	1.700	4.17	4.618	18.86	3.151	16.50	10.	11.63
9	OSOLV3	2	.352	.86	1.181	4.82	1.021	5.34	2.	2.33
10	OGETST	2	9.722	23.86	.589	2.41	.471	2.46	12.	13.95
11	OSCINC	2	6.204	15.23	1.375	5.62	1.080	5.65	9.	10.47
TOTALS:			40.745		24.480		19.100		86.	

```
TOTAL TIME IN MONITOR:        .084 SECONDS
  MFC    NSROC 6400 NOS/BE   1.2  H+2079226
17.33.46.CSPRSLQ  FROM    /768  RUN ON 6400
17.33.46.IP  C0000064 WORDS - FILE INPUT  , DC 04
17.33.46.CSPRSTR,CM277000,T99,PC.
17.33.48. BLOCK TIME
17.33.48.ATTACH,NEWIN,RSCNEWIN,ID=CSRO.
17.33.48.PF CYCLE NO. = 003
17.33.48.ATTACH,PROG,E2NODTITSK,ID=CSMC,LC=1.
17.33.48.PF CYCLE NO. = 001
17.33.48.PROG,NEWIN.
```

A SIMPLE EXAMPLE
FIGURE 3.9 - 'SUBSTRC' OUTPUT (CONT'D)

```
17.34.42. ***** LAST TAPES  2  8 *****
17.34.42.MARC
17.35.19.     STOP    - NORMAL TERMINATION
17.35.19.     40.865 CP SECONDS EXECUTION TIME
17.35.19.OP  00013568 WORDS - FILE OUTPUT , DC 40  ( PRINT )
17.35.19.MS   14336  WORDS  (  118272 MAX USED)
17.35.19.CPA     41.876 SEC.
17.35.19.IO      20.556 SEC.
17.35.19.AWC  76639.822
17.35.19.SS      54.210 SEC.
17.35.19.PP      28.097 SEC.     DATE 08/17/79
17.35.19.EST. BASIC CHARGE $    6.92
17.35.19.EJ  END OF JOB, 760
```

CHAPTER 4

'ADTOC'

ADD DISPLACEMENTS

TO ORIGINAL COORDINATES

4.1 INTRODUCTION

THE AIM IS TO PRODUCE A FILE WHICH CAN BE USED TO DISPLAY A DISPLACED STRUCTURE ON SOME GRAPHICAL DEVICE. WE ARE CURRENTLY USING THE PROGRAM 'STAGING' FOR THIS PURPOSE (STAGINREF).

'ADTOC' SCALES THE DISPLACEMENTS PRODUCED BY 'SUBSTRC' AND ADDS THESE SCALED DISPLACEMENTS TO THE ORIGINAL COORDINATES. SCALING IS OFTEN NECESSARY TO PRODUCE VISIBLE DEFORMATIONS OF A STRUCTURE.

'ADTOC' IS USED IN CONJUNCTION WITH THE PROGRAM 'STON', WHICH TRANSLATES A FILE FROM 'SUBSTRUC' INTERMEDIATE FILE FORMAT TO THE 'NASTRAN' BULK DATA FORMAT.

4.2 DEFAULTS AND LIMITATIONS

THE DEFAULT MAGNITUDE OF 'SCALE', WHICH MULTIPLIES THE DISPLACEMENTS IS 50. YOU SHOULD PROBABLY TRY TO USE A SCALE FACTOR WHICH PRODUCES A MAXIMUM DISPLACEMENT OF 10 PERCENT OF THE LARGEST DIMENSION OF THE STRUCTURE (FOR VISIBLILITY).

THE MAXIMUM NUMBER OF NODES IN ANY SUBSTRUCTURE WHICH CAN BE ACCOMMODATED BY 'ADTOC' IS 512. THE MAXIMUM NUMBER OF SUBSTRUCTURES IS 64. THESE MAY BE INCREASED BY MODIFYING THE SOURCE CODE.

4.3 USING THE PROGRAM

THE FOLLOWING CONTROL CARDS ARE SUFFICIENT TO EXECUTE "ADTOC':

```
ATTACH,ADTOC,ID=CSPR.
ADTOC.
```

4.3.1 DEFAULT EXECUTION

```
ADTOC,INPUT,NEWIN,TAPE61,OUTPUT,INFILE.
```

4.3.2 FILES

INPUT	THIS FILE CONTAINS AT MOST TWO CARDS. CARD 1 CONTAINS 'SCALE', A REAL NUMBER ENTERED IN FREE FORMAT. DEFAULT VALUE IS 50.0. CARD 2 CONTAINS 'MAXDEG', THE MAXIMUM NUMBER OF DEGREES OF FREEDOM AT A NODE IN THIS ANALYSIS. THE DEFAULT IS 9. IF THE DEFAULT VALUES ARE APPROPRIATE, <INPUT> MAY BE AN EMPTY FILE.
NEWIN	THE DATA FILE PRODUCED BY THE PROGRAM 'WABS'
TAPE61	THE FILE OF DISPLACEMENTS FROM 'SUBSTRC'
OUTPUT	PRINTED OUTPUT FROM 'ADTOC'
INFILE	THIS FILE IS IN THE SAME FORMAT AS <NEWIN> AND CONTAINS THE NODAL TOPOLOGY (CONNECTIVITY) AND THE MODIFIED COORDINATES.

4.4 EXAMPLE

THIS EXAMPLE SHOWS THE PRODUCTION OF THE FILE <NEWIN> BY 'WABS' AND THE FILE <INFILE> BY 'ADTOC'. THE FILE <TAPE61> IS ASSUMED TO HAVE BEEN PRODUCED AND CATALOGED IN AN EARLIER ANALYSIS PERFORMED WITH 'SUBSTRC".

ADTOC
EXAMPLE

```
COMMENT.----------------------------------------
COMMENT. PRODUCE FILE <NEWIN>.
COMMENT.----------------------------------------
ATTACH,WABS,ID=CSPR.
ATTACH,DATA,YOURDATA,ID=YOUR.
WABS.
UNLOAD,WABS,DATA.
COMMENT.----------------------------------------
COMMENT. ADD DISPLACEMENTS, PRODUCE <INFILE>
COMMENT.----------------------------------------
ATTACH,TAPE61,YOURTAPE61,ID=YOUR.
ATTACH,ADTOC,ID=CSPR.
ADTOC.
UNLOAD,ADTOC.
```

AT THIS POINT, THE FILE <INFILE> EXISTS, WHICH IS IN THE SAME FORMAT AS THE 'SUBSTRC' INPUT FILE <NEWIN>. TO CONTINUE, AND PREPARE THE DATA FOR DISPLAY WITH A DISPLAY PACKAGE, ONE MUST TRANSLATE THIS DATA INTO A FORM COMPATIBLE WITH THE PLOTTING DEVICE. IF, FOR EXAMPLE, THE DISPLAY IS TO BE DONE WITH 'STAGING', THE FOLLOWING CONTROL CARDS WOULD BE EXECUTED IMMEDIATELY FOLLOWING THE ABOVE:

```
COMMENT.----------------------------------------
COMMENT. TRANSLATE TO NASTRAN INPUT FILE <DATA>
COMMENT.----------------------------------------
ATTACH,STON,ID=CSPR.
STON,INFILE.
UNLOAD,STON.
ATTACH,PROCFIL,PROCFILPRESTAG,ID=CAMK.
BEGIN,IDEALTK,,DB=DBNAME,ID=YOUR,STR1=STRUCTUREN,
   STR2=AMEUPTO40C,STR3=HARACTERSL,STR4=ONG,
   SUB1=UPTO40CHAR,SUB2=SUBSTRUCTU,SUB3=RENAME.
```

CHAPTER 5

'BEAMX'

GENERATE COORDINATES FOR OPEN SECTION BEAM ELEMENTS (TYPE #13)

5.1 INTRODUCTION

'BEAMX' WAS WRITTEN TO ASSIST IN THE PREPARATION OF COORDINATE DATA FOR THE OPEN SECTION BEAM ELEMENT (TYPE #13) IN THE 'MARC' PROGRAMS. THE GEOMETRIC DEFINITIONS OF EACH GRID POINT FOR ELEMENT 13 REQUIRE 3 CARTESIAN COORDINATES (X, Y, Z), THE DERIVATIVES OF THESE COORDINATES WITH RESPECT TO THE ARC LENGTH 'S', (DX/DS, DY/DS, DZ/DS), 3 COMPONENTS OF A UNIT VECTOR IN THE DIRECTION OF THE 'X' AXIS WHICH DEFINES THE BEAM CROSS SECTION (AX, AY, AZ), THE DERIVATIVES OF THESE COMPONENTS WITH RESPECT TO ARC LENGTH 'S' (DAX/DS, DAY/DS, DAZ/DS), AND FINALLY, THE ARC LENGTH AT THE GRIPOINT 'S'. THUS, EACH NODE IS DEFINED BY A TOTAL OF 13 COORDINATES. 'BEAMX' SHORTENS THE TIME NECESSARY TO PREPARE THESE DATA, AND ENSURES THAT THEY ARE EXPRESSED IN PROPER TERMS.

'BEAMX' IS WRITTEN IN FORTRAN 4. IT IS SMALL, AND EASILY MODIFIED.

5.2 FILES

THE FOLLOWING FILES ARE USED BY 'BEAMX':

INPUT	USER INPUT
OUTPUT	PRINTED OUTPUT
TAPE7	FILE OF GENERATED COORDINATES

5.3 EXECUTION

5.3.1 AS A BATCH JOB:

TO RUN 'BEAMX' AS A BATCH JOB, ONE MAY EXECUTE THE FOLLOWING CONTROL CARDS:

```
JOB,CM35000,...
CHARGE,YOUR,GOBBLYGOOK.
ATTACH,BEAMX,BEAMXLGO,ID=CSPR.
ATTACH,IN,YOURINPUTTOBEAMX,ID=YOUR.
REQUEST,TAPE7,*PF.
MAP,OFF.
BEAMX,IN.
CATALOG,TAPE7,YOURBEAMCOORDINATES,ID=YOUR.
```

NOTE THAT IN THE ABOVE, IT IS ASSUMED THAT THE INPUT FILE <IN> HAS BEEN CREATED IN SOME OTHER JOB (POSSIBLY USING ONE OF THE SYSTEM TEXT EDITORS). <TAPE7> MAY LATER BE ATTACHED INTERACTIVELY AND THE DATA INSERTED INTO THE ANALYSIS INPUT FILE AT THE APPROPRIATE PLACES.

5.3.2 AS AN INTERACTIVE JOB:

TO EXECUTE 'BEAMX' INTERACTIVELY, THE FOLLOWING COMMANDS MAY BE ISSUED:

```
ATTACH,BEAMX,BEAMXLGO,ID=CSPR.
ATTACH,INPUT,YOURINPUTTOBEAMX,ID=YOUR.
REQUEST,TAPE7,*PF.
MAP,OFF.
BEAMX.
```

NOTE THAT IN THE ABOVE, IT IS ASSUMED THAT THE INPUT FILE <INPUT> HAS BEEN CREATED IN SOME OTHER JOB (POSSIBLY USING ONE OF THE SYSTEM TEXT EDITORS). AT THIS POINT, <TAPE7> EXISTS AS A LOCAL FILE AT YOUR TERMINAL. IT MAY BE FURTHER MANIPULATED WITH OTHER

SYSTEM TOOLS, CATALOGED, ETC. AFTER EXECUTION INTERACTIVELY, THE OUTPUT MAY BE ROUTED TO A PRINTER, OR SCANNED AT THE TERMINAL ITSELF.

5.3.3 DEFAULT EXECUTION

THE DEFAULT EXECUTION OF 'BEAMX' IS:

```
BEAMX,INPUT,OUTPUT,TAPE7.
```

5.4 THE <INPUT> FILE

THE INPUT DATA ARE THE MINIMUM REQUIRED TO COMPLETELY DEFINE THE GEOMETRY OF THE BEAM. NOTE THAT THIS FILE IS NOT (THAT IS NOT!) FREE FORMAT! ALL NUMBERS MUST BE ENTERED WITHIN THE FIELDS ON THE CARD SPECIFIED. INTEGERS ARE ENTERED WITHOUT A DECIMAL POINT, RIGHT JUSTIFIED IN THE FIELD. REALS ARE ALWAYS ENTERED WITH A DECIMAL POINT.

CAUTION!

'BEAMX' DOES NO ERROR CHECKING!

'BEAMX'
<INPUT> FILE

(1) CARD 1

NOTES	COLS	VARIABLE	
(2)	1-3	FLAG	'OLD', OR, OMIT ENTIRELY.

CARD 2

NOTES	COLS	VARIABLE	
(3)	1-5	ICASE	NUMBER OF BEAMS TO GENERATE

CARD 3.1

NOTES	COLS	VARIABLE	
(4)	1-5	IBMTYP	TYPE OF BEAM. 1: CIRCUMFERENTIAL ON A CYLINDER; 2: LONGITUDINAL ON A CYLINDER
	6-10	NUMND	NUMBER OF GRIDPOINTS ON THE BEAM

(5) CARD 3.2

NOTES	COLS	VARIABLE	
	1-5	NODE1	NUMBER OF FIRST NODE
	6-10	NODE2	NUMBER OF SECOND NODE
	...	NODEN	NODE NUMBER 'NUMND'

CARD 3.3

NOTES	COLS	VARIABLE	
(6)	1-10	R	RADIUS OF CYLINDER

CARD 3.4

NOTES	COLS	VARIABLE	
(7)	1-10	Z(1)	Z LOCATION OF FIRST NODE
	11-20	Z(2)	Z LOCATION OF SECOND NODE
	...		

CARD 3.5

NOTES	COLS	VARIABLE	
(8)	1-10	THETA(1)	ANGLE TO FIRST NODE, DEGREES
	11-20	THETA(2)	ANGLE TO SECOND NODE
	...		

NOTES:

1. 'BEAMX' MAY PRODUCE COORDINATES ON <TAPE7> IN EITHER OF TWO FORMATS: 'NEW', WHICH IS THE DEFAULT, AND 'OLD', WHICH IS COMPATIBLE WITH THE 'WABS' INTERMEDIATE FILE <NEWIN> AS WELL AS 'MARCCDC' AND 'TRAINS'. IF 'WABS' FORMAT DATA IS DESIRED ON <TAPE7>, OMIT THIS CARD ENTIRELY.

2. THIS INPUT IS CHARACTER INPUT.

'BEAMX'
<INPUT> FILE: NOTES

3. 'ICASE' IS THE NUMBER OF BEAMS GENERATED. THUS, CARDS 3.1 THRU 3.5 ARE REPEATED AS A SET 'ICASE' TIMES.

4. CIRCUMFERENTIAL BEAMS ARE FAMILIAR TO ANALYSTS OF RING STIFFENED CYLINDERS AS 'FRAMES'. LONGITUDINAL BEAMS ARE 'STRINGERS'.

5. NODE NUMBERS ARE INTEGERS. THEY ARE ENTERED RIGHT JUSTIFIED IN THE FIELDS ON THIS CARD. SINCE EACH NODE NUMBER REQUIRES 5 COLUMNS, IT IS POSSIBLE TO INPUT A MAXIMUM OF 16 NODES PER CARD. IF THERE ARE MORE THAN 16 NODES TO BE INPUT, MERELY ENTER THEM ON SUCCESSIVE CARDS IN 5 COLUMN FIELDS UNTIL THE TOTAL OF 'NUMND' NODES HAS BEEN ENTERED.

6. THE RADIUS R IS A REAL NUMBER, AND MUST BE ENTERED WITH A DECIMAL POINT.

7. Z COORDINATES ARE REAL NUMBERS, ENTERED WITH A DECIMAL POINT. NOTE THAT A SINGLE Z COORDINATE IS REQUIRED FOR CICRCUMFERENTIAL BEAMS, WHEREAS A LONGITUDINAL BEAM REQUIRES 'NUMND' Z COORDINATES. 'BEAMX' DETERMINES THE AMOUNT NEEDED, AND READS UNTIL IT IS SATISFIED. SINCE EACH 'Z' OCCUPIES 10 COLUMNS, IT IS POSSIBLE TO PUT A MAXIMUM OF 8 'Z'S ON A CARD. IF YOU NEED MORE, MERELY CONTINUE ENTERING 'Z'S ON SUCCESSIVE CARDS IN 10 COLUMN FIELDS UNTIL THE TOTAL REQUIRED HAS BEEN ENTERED.

8. EACH ANGLE 'THETA(I)' IS A REAL NUMBER, ENTERED WITH A DECIMAL POINT. NOTE THAT THERE ARE 'NUMND' VALUES REQUIRED FOR A CIRCUMFERENTIAL BEAM, WHILE THERE IS ONLY 1 REQUIRED FOR A LONGITUDINAL BEAM. 'THETA' MEASURES THE ANGLE TO THE BEAM FROM THE X-Z PLANE TO THE NODE. SINCE EACH 'THETA' OCCUPIES 10 COLUMNS, IT IS POSSIBLE TO PUT A MAXIMUM OF 8 'THETA'S ON A CARD. IF YOU NEED MORE, MERELY CONTINUE ENTERING 'THETA'S ON SUCCESSIVE CARDS IN 10 COLUMN FIELDS UNTIL THE TOTAL REQUIRED HAS BEEN ENTERED.

5.5 LIMITATIONS AND REMARKS

1. MINIMUM FIELD LENGTH TO EXECUTE 'BEAMX': APPROXIMATELY 35000 WORDS

2. MACHINE: CDC 6000

3. TIME ESTIMATE: .005 SECONDS PER NODE

4. PROGRAM MAINTENANCE: 'BEAMX' IS WRITTEN IN FORTRAN AND MAINTAINED BY THE AUTHOR. THE SOURCE CODE IS RETAINED AS THE SOURCE FILE BEAMXSOURCE ,ID=CSRO. THE RELOCATABLE (OBJECT) CODE IS RETAINED AS BEAMXLGO ,ID=CSPR. BOTH THE SOURCE AND THE RELOCATABLE ARE RETAINED ON PRIVATE DISK DV4717 AT THE DTNSRDC CDC6400.

CHAPTER 6

'CM'

CENTRAL MEMORY NECESSARY FOR AN ANALYSIS

6.1 INTRODUCTION

'CM' WAS WRITTEN TO COMPUTE THE AMOUNT OF COMPUTER MEMORY NEEDED FOR AN ANALYSIS.

ESTIMATES OF STORAGE ARE SOMETIMES NECESSARY PRIOR TO ANY ANALYSIS MERELY TO DETERMINE IF AN ANALYSIS OF THE ENVISIONED SIZE WILL EXCEED THE CAPACITY OF THE 'SUBSTRC' PROGRAM. THIS FORCES AN ANALYST TO APPROXIMATE THE SIZE OF THE ANALYSIS BY GAZING AT THE CEILING AND GUESSING (IN A RATHER ROUGH WAY) HOW THE STRUCTURE WILL BE DIVIDED.

ESTIMATING IS MADE DIFFICULT BY THE DYNAMIC STORAGE ALLOCATION PROCESS USED BY 'SUBSTRC'. THE STORAGE USED IN ANY ANALYSIS IS PROBLEM DEPENDENT; THAT IS, THE STORAGE REQUIRED VARIES FROM CASE TO CASE IN A NON-LINEAR FASHION. THE ALLOCATION ALGORITHM IS QUITE SIMPLE LOGICALLY BUT INCREDIBLY COMPLEX ARITHMETICALLY, AND IS IDEALLY SUITED TO MACHINE SOLUTION.

IT IS TRUE THAT THE 'SUBSTRC' PROGRAM ITSELF COULD BE USED TO DETERMINE THE STORAGE ALLOCATION WITHOUT EMPLOYING A SEPARATE PROGRAM. HOWEVER, 'SUBSTRC' IS A LARGE PROGRAM AND REQUIRES ABOUT HALF OF THE AVAILABLE MACHINE RESOURCES MERELY TO BEGIN OPERATION. WITH OTHER JOBS RUNNING IN A MULTIPROGRAMMING ENVIRONMENT, THE RESPONSE FROM 'SUBSTRC' IS THUS SLOW. 'CM' IS A SMALL PROGRAM WHICH PROVIDES RAPID TURNAROUND, AND IS CHEAP TO RUN. IT IS THEREFORE PREFERABLE FOR THE TASK OF DETERMINING THE CENTRAL MEMORY REQUIREMENTS.

'CM' PROVIDES A LOOP ON THE 'SUBSTRC' VARIABLE 'MXRD', WHICH IS THE NUMBER OF ROWS OF SUBSTRUCTURE STIFFNESS MATRIX WHICH CAN FIT INTO CENTRAL MEMORY AT ANY TIME. IT IS PREFERABLE TO HAVE THE LARGEST 'MXRD' POSSIBLE TO REDUCE THE AMOUNT OF CENTRAL PROCESSOR TIME USED IN PERFORMING INPUT/OUTPUT OPERATIONS. 'CM' SETS 'MXRD' TO THE VALUE OF 'MAXNP' (THE MAXIMUM OF: THE MAXIMUM HALF BANDWIDTH IN A SUBSTRUCTURE, THE MAXIMUM CONNECTIVITY IN A SUBSTRUCTURE. SEE NOTES BELOW). IF THE ANALYSIS WILL FIT INTO THE ARRAY SPACE AVAILABLE, 'CM' STOPS, PRINTING THESE SIZES. IF THE ANALYSIS WILL NOT FIT INTO THE ARRAY SPACE AVAILABLE, 'MXRD' IS REDUCED BY 1, AND THE ALGORITHM IS EXECUTED AGAIN. THIS ITERATION IS PERFORMED UNTIL THE ANALYSIS FITS, OR 'MXRD' IS LESS THAN 1.

CM
INTRODUCTION

'CM' PRINTS THE ARRAY SIZES NECESSARY FOR PROBLEM SOLUTION. IF THE ANALYSIS WILL NOT FIT WITH THE GIVEN PARAMETERS, RETHINK THE ANALYSIS AND SUBSTRUCTURE IT DIFFERENTLY. IF THE ANALYSIS WILL NOT FIT AFTER SEVERAL ATTEMPTS TO SIZE IT, CONTACT DTNSRDC CODE 1720.3.

6.2 FILES

THE FOLLOWING FILES ARE USED BY 'CM':

INPUT	USER INPUT (SAME FORMAT AS THE 'SUBSTRC' FILE <NEWIN>
OUTPUT	PRINTED OUTPUT

6.3 EXECUTION

6.3.1 AS A BATCH JOB:

TO RUN 'CM' AS A BATCH JOB, ONE MAY EXECUTE THE FOLLOWING CONTROL CARDS:

```
JOB,CM35000,...
CHARGE,YOUR,GOBBLYGOOK.
ATTACH,CM,CMLGO,ID=CSPR.
ATTACH,IN,YOURINPUTTOCM,ID=YOUR.
MAP,OFF.
CM,IN.
```

NOTE THAT IN THE ABOVE, IT IS ASSUMED THAT THE INPUT FILE HAS BEEN CREATED IN SOME OTHER JOB (POSSIBLY USING ONE OF THE SYSTEM TEXT EDITORS).

6.3.2 AS AN INTERACTIVE JOB:

TO EXECUTE 'CM' INTERACTIVELY, THE FOLLOWING COMMANDS MAY BE ISSUED:

```
ATTACH,CM,CMLGO,ID=CSPR.
MAP,OFF.
CM.
```

NOTE THAT IN THE ABOVE, IT IS ASSUMED THAT THE INPUT FILE HAS BEEN CREATED IN SOME OTHER JOB (POSSIBLY USING ONE OF THE SYSTEM TEXT EDITORS). AFTER EXECUTION INTERACTIVELY, THE OUTPUT MAY BE ROUTED TO A PRINTER, OR SCANNED AT THE TERMINAL ITSELF.

6.3.3 DEFAULT EXECUTION

THE DEFAULT EXECUTION OF 'CM' IS:

```
CM,INPUT,OUTPUT.
```

6.4 THE <INPUT> FILE

THE <INPUT> FILE IS COMPRISED OF THE FIRST NINE CARDS OF THE 'WABS' INTERMEDIATE FILE <NEWIN>. USING ONE OF THE SYSTEM EDITORS, AND THE FREE FORMAT PROGRAM 'FREEIN', THESE CARDS MAY BE EASILY CREATED. NOTE THAT THIS FILE IS NOT (THAT IS: NOT!) FREE FORMAT. ALL NUMBERS ARE INTEGERS (WITH THE EXCEPTION OF THE FIRST CARD) AND MUST BE ENTERED RIGHT JUSTIFIED IN THE FIELDS SPECIFIED.

CAUTION!

'CM' DOES NO ERROR CHECKING!

NOTES	COLS	VARIABLE	
	CARD 1		
	1-76	LABEL	76 COLUMNS OF TITLE

NOTES	COLS	VARIABLE	
(1)	CARD 2		
(2)	1-10	MAXALL	SIZE OF COMMON /SPACE/
	11-15	IDIM	GO/NOGO SWITCH (SET = 0)
	16-20	IRD1	LENGTH OF INDEX FOR <TAPE12> (DEFAULT: 50)
	21-25	IRD2	LENGTH OF INDEX FOR <TAPE14> (DEFAULT: 50)

CM
<INPUT> FILE

NOTES	COLS	VARIABLE	
	CARD 3		
	1-5	NELTYP	NUMBER OF ELEMENT TYPES (MAXIMUM OF 3 PERMITTED)
	6-10	J1	ELEMENT TYPE 1
	11-15	J2	ELEMENT TYPE 2
	16-20	J3	ELEMENT TYPE 3

NOTES	COLS	VARIABLE	
	CARD 4		
	1-5	ISI	FLAG FOR LARGE DISPLACEMENT ANALYSIS (SET = 1)
	6-10	IRESID	NOT USED (SET = 0)
	11-15	KINHRD	FLAG FOR KINEMATIC HARDENING (SET = 1 FOR KINEMATIC HARDENING, = 0 FOR ISOTROPIC HARDENING)
	16-20	LODCOR	FLAG FOR LOAD CORRECTION (SET = 1)

NOTES	COLS	VARIABLE	
	CARD 5		
	1-5	ICRT	MATRIX SOLUTION FLAG
(3)	6-10	MAXNP	MAXIMUM NODAL CONNECTIVITY
(3)	11-15	MAXBW	MAXIMUM NODAL BANDWIDTH/2
	16-20	MXRD	NUMBER OF IN-STORE ROWS OF STIFFNESS MATRIX (SET = 0)
	21-25	IELAS	ELASTIC STORAGE FLAG (SET = 0)

NOTES	COLS	VARIABLE	
	26-30	IPRBLD	FLAG FOR BUILDING SUBSTRUCTURE TAPE (SET = 0)
	31-35	ITIEM	MAXIMUM NUMBER OF TIES IN A SUBSTRUCTURE
	36-40	ISTYPM	NUMBER OF TYPES OF TIES
(4)	41-45	LONGTM	NUMBER OF RETAINED NODES PLUS 1
(5)	46-50	NUMDIS	NUMBER OF TYPES OF DISTRIBUTED LOADS

NOTES	COLS	VARIABLE	
	CARD 6		
	1-5	MESHR	INPUT TAPE NUMBER (SET = 0)
	5-10	IPLOT	NOT USED (SET = 0)
	11-15	IRSTRT	NOT USED (SET = 0)
	16-20	IELSTO	ELEMENT STORAGE FLAG (SET = 1)

NOTES	COLS	VARIABLE	
	CARD 7		
	1-5	NUMEL	MAXIMUM ELEMENTS IN A SUBSTRUCTURE
	6-10	NUMNP	MAXIMUM NODES IN A SUBSTRUCTURE
	11-15	NUMBC	MAXIMUM BOUNDARY CONDITIONS IN A SUBSTRUCTURE
(6)	16-20	NSTRES	STRESS LOCATION FLAG

NOTES	COLS	VARIABLE	
	21-25	DUMMY	NOT USED (SET = 0)
	26-30	NBCTMX	MAXIMUM BOUNDARY CONDITION TRANSFORMATIONS IN A SUBSTRUCTURE
	31-35	MPTPMX	MAXIMUM TRANSFORMATIONS IN A SUBSTRUCTURE

NOTES	COLS	VARIABLE	
	CARD 8		
(7)	1-5	MPRMAX	MAXIMUM PRESSURE LOADS IN A SUBSTRUCTURE
	6-10	NPIMAX	MAXIMUM INTERNAL NODES IN A SUBSTRUCTURE, I.E., NODES WHICH DO NOT CONNECT WITH OTHER SUBSTRUCTURES.
	11-15	NPBMAX	MAXIMUM NODES ON A SUBSTRUCTURE EDGE, I.E., NODES WHICH CONNECT WITH OTHER SUBSTRUCTURES.
	16-20	NUMMAX	MAXIMUM NODES IN A SUBSTRUCTURE (SAME AS 'NUMNP' OF CARD 7).
	21-25	NSTCON	NUMBER OF SUBSTRUCTURES
(8)	26-30	NTPBO	TOTAL EDGE CONNECTIONS
	31-35	NNIMIN	MINIMUM NUMBER OF INTERNAL NODES IN A SUBSTRUCTURE (SET = 1)
(9)	36-40	MAXBWO	MAXIMUM BANDWIDTH/2 OF INTERSUBSTRUCTURE CONNECTIVITY
	41-45	ISUBXP	MATRIX SOLUTION FLAG (SET = 1)

CM
<INPUT> FILE

NOTES	COLS	VARIABLE	
	CARD 9		
	1-5	MASTRS	MATRIX SOLUTION FLAG (SET = 0)
	6-10	LASTRS	SUBSTRUCTURE RESTART FLAG (SET = 0)
	11-15	Q	NUMBER OF RESTART TAPE (SET = 0)
	16-20	O	NUMBER OF RESTART TAPE (SET = 0)
	21-25	IPROV	MATRIX SOLUTION FLAG (SET = 1)

NOTES:

1. THE CURRENT ACTIVE DIMENSIONS IN THE 'SUBSTRC' PROGRAM MAY BE OBTAINED FROM DTNSRDC CODE 1720.3.

2. MAXIMUM 'MAXALL' AS OF THIS WRITING IS 63000.

3. 'MAXNP' IS THE MAXIMUM NUMBER OF NODES CONNECTED TO A NODE, INCLUDING TIES. THIS IS IMPOSSIBLE TO DETERMINE CORRECTLY WITHOUT ACCURATE KNOWLEDGE OF THE 'SUBSTRC' CONNECTIVITY ALGORITHM. PRECISE COUNTS OF CONNECTIVITY 'MAXNP' AND NODAL HALF BANDWIDTH 'MAXBW' ARE CALCULATED BY 'WABS'. THE INTERESTED READER IS DIRECTED TO THE 'WABS' PROGRAM MODULES WHICH PERFORM THIS CALCULATION USING EXTREMELY FAST REGISTER ARITHMETIC (PROCESSING BITS RATHER THAN NUMBERS). THESE ROUTINES ARE: KIIBAND, KIIBAN1, BNDWDTH, KIIBA11, LMNBITS, KIIBA21, AND KIIBA31.

4. ADD 1 TO THE MAXIMUM NUMBER OF NODES INVOLVED IN ANY TIE, AND ENTER THIS NUMBER.

5. 'NUMDIS' IS ACTUALLY THE NUMBER OF ALTERATIONS OF THE MAGNITUDE OF THE DISTRIBUTED LOADS IN ANY SUBSTRUCTURE. FOR EXAMPLE, IF THE LOAD ON ELEMENT 1 IS 1.0 PSI, ELEMENT 2 IS NOT LOADED, AND THE LOAD ON ELEMENT 3 IS 1.0 PSI, THE INTERPRETATION IS: ELEMENT 1 IS LOADED WITH 1.0 PSI, ELEMENT 2 IS LOADED WITH 0.0 PSI, AND ELEMENT 3 IS LOADED WITH 1.0 PSI. 'NUMDIS' IS THEREFORE 3, BECAUSE THERE ARE 3 ALTERNATIONS OF LOAD MAGNITUDE.

6. 'NSTRES' IS SET = 0 WHEN STRESSES ARE TO BE EVALUATED AT A SINGLE POINT WITHIN AN ELEMENT (USUALLY THE CENTROID). WHEN 'NSTRES' IS SET = 1, STRESSES ARE EVALUATED AT ALL INTEGRATION POINTS.

7. 'MPRMAX' IS THE COUNT OF THE ACTUAL DISTINCT NON-ZERO PRESSURE LOADS ON A SUBSTRUCTURE. FOR EXAMPLE, IF THE LOAD ON ELEMENT 1 IS 1.0 PSI, ELEMENT 2 IS NOT LOADED, AND THE LOAD ON ELEMENT 3 IS 1.0 PSI, THE INTERPRETATION IS THAT 'MPRMAX' = 1, BECAUSE THERE IS 1 DISTINCT NON-ZERO PRESSURE LOAD.

8. 'NTPBO' IS THE LENGTH OF THE INTER SUBSTRUCTURE CONNECTIVITY ARRAY. SINCE MORE THAN ONE SUBSTRUCTURE MAY BE JOINED AT AN EDGE, THIS IS NOT STRICTLY THE SUM OF ALL THE EDGE NODES, BUT RATHER THE EDGE CONNECTIVITY.

9. 'MAXBWO' IS SIMPLY THE MAXIMUM SUBSTRUCTURE TO SUBSTRUCTURE CONNECTIVITY.

6.5 LIMITATIONS AND REMARKS

1. IT WOULD BE INSTRUCTIVE TO READ THE 'CM' PROGRAM TO APPRECIATE THE 'SUBSTRC' DYNAMIC STORAGE ALLOCATION PROCEDURE.

2. MINIMUM FIELD LENGTH TO EXECUTE 'CM': APPROXIMATELY 35000 WORDS.

3. MACHINE: CDC 6000

4. TIME ESTIMATE: 5 SECONDS.

LIMITATIONS AND REMARKS

5. PROGRAM MAINTENANCE: 'CM' IS WRITTEN IN FORTRAN AND IS MAINTAINED BY THE AUTHOR. THE SOURCE CODE IS RETAINED AS A SOURCE INPUT FILE TO THE 'UPDATE' UTILITY AS CMUI ,ID=CSRO. THE PROGRAM ITSELF IS RETAINED IN RELOCATABLE FORM AS CMLGO ,ID=CSRO. BOTH THE SOURCE AND RELOCATABLE FILES ARE RETAINED ON PRIVATE DISK DV4717 AT THE DTNSRDC CDC6400.

CHAPTER 7

'DFLSIFT'

SIFT DISPLACEMENTS

7.1 INTRODUCTION

'DFLSIFT' IS AN INTERFACE BETWEEN THE 'SUBSTRC' PROGRAM ELEMENT TYPE 8 (DOUBLY CURVED SHELL TRIANGLE) AND THE UNIVERSITY OF CALGARY PLOTTING PROGRAM 'CONT' (REFERENCE {CONT}). AS SUCH, IT PROCESSES THE 'SUBSTRC' INTERMEDIATE DATA FILE <NEWIN> AND THE SUBSTRC DISPLACEMENT OUTPUT FILE <TAPE61> TO PRODUCE A FILE <DATA> COMPATIBLE WITH THE BULK OF THE INPUT DATA TO 'CONT'. 'DFLSIFT' MAKES 2 ADDITIONAL FILES WHICH MAY BE REUSED FOR FURTHER SIFTING.

'DFLSIFT' IS DESIGNED TO FILTER THE 'SUBSTRC' INTERMEDIATE FILE <NEWIN> WITH USER-DEFINED FILTERS. THUS, 'DFLSIFT' WILL PUT ON THE OUTPUT FILE <DATA> ONLY THOSE ELEMENTS AND COORDINATES WHICH PASS THRU THE FILTER(S). YOU ALSO HAVE THE OPTION OF UNROLLING AN AXISYMMETRIC SURFACE ABOUT ONE OF 3 AXES.

'DFLSIFT' IS DESIGNED TO LOGICALLY AND ACTUALLY SEPARATE EACH SPECIFIC TASK INTO A SINGLE MODULE OR SUBROUTINE. THIS KIND OF CONSTRUCTION MAKES FURTHER CHANGES TO 'DFLSIFT' FEASIBLE BY OTHER THAN THE ORIGINAL DESIGNER. IT IS WRITTEN IN FORTRAN.

7.2 FILES

INPUT	USER INPUT. SECTION 3 OF THIS REPORT GIVES DETAILED EXPLANATIONS OF USER INPUT.
OUTPUT	PRINTED OUTPUT - USUALLY ABOUT A PAGE OR TWO. THE MAXIMUM, MINIMUM AND DIFFERENCES OF THE COORDINATES AND THE DISPLACEMENTS ARE PRINTED HERE, WHICH ALLOWS YOU TO GET AN IDEA OF WHAT THE INPUT TO 'CONT' SHOULD BE.
NEWIN	THE INTERMEDIATE 'SUBSTRC' FILE PRODUCED BY 'WABS'

DFLSIFT
FILES

DATA	THE CODED 'DFLSIFT' OUTPUT FILE SUITABLE FOR FURTHER PROCESSING, POSSIBLY BY A PLOTTING PROGRAM. IT CONTAINS ONE PARTITION FOR EACH OF THE DISPLACEMENTS. EACH PARTITION ENDS WITH A FORTRAN WRITTEN 'ENDFILE' MARK. EACH PARTITION CONTAINS N RECORDS, WHERE N IS THE NUMBER OF NODES PASSED THRU THE USER-DEFINED FILTERS. THE FORMAT OF EACH RECORD ON THE DATA FILE IS (3E15.7,I2). EACH RECORD IN EACH PARTITION CONTAINS X, Y, Z, FLAG WHERE: X IS THE REAL X COORDINATE OF THE INTEGRATION POINT, Y IS THE REAL Y COORDINATE OF THE INTEGRATION POINT, Z IS THE REAL DISPLACEMENT VALUE AT THE NODE. FLAG IS AN INTEGER WHICH SIGNALS THE END OF THE DATA. FLAG = 0 MEANS MORE DATA FOLLOWS; FLAG = 99 SIGNALS END OF DATA.
MSXYZ	THE MASS STORAGE COORDINATES FILE MADE BY 'DFLSIFT'. IT CONTAINS ALL THE COORDINATES NUMBERED SEQUENTIALLY. IT HAS NO REFERENCES TO SUBSTRUCTURES AT ALL. THIS FILE IS SAVABLE.
MSDISP	THE MASS STORAGE DISPLACEMENT FILE MADE BY 'DFLSIFT'. IT CONTAINS ALL THE DISPLACEMENTS PRODUCED BY 'SUBSTRC' AT ALL THE NODES. IT HAS NO REFERENCES TO SUBSTRUCTURES AT ALL. THIS FILE IS SAVABLE.

7.2.1 A NOTE ON THE <DATA> FILE

TO MAKE THINGS EASIER TO HANDLE WHEN YOU ARE VIEWING THE DISPLACEMENTS ON A 'SCOPE, YOU MAY WANT TO USE THE PROCEDURE CRUMBLE TO BREAK THE DATA FILE INTO PIECES (OF COURSE, CRUMBLE MAY BE USED AT ANY TIME).

TO CREATE A FILE WHICH DOES NOT HAVE ANY END-FILE MARKS (THAT IS, THE FILE IS ONE HUGE PARTITION), USE THE

COPYS SYSTEM UTILITY (DESCRIBED MORE FULLY IN REFERENCE {CCRM}) AS FOLLOWS:

```
BEGIN,COPYS,,COPYJ,DATA,NEWFIL.
REWIND NEWFIL.
```

NOTE THAT THE INPUT DATA EXPECTED BY 'CONT' IS TO COME FROM TAPE8, TAPE9, OR TAPE10, SO YOU MAY HAVE TO LOCALLY RENAME THE DATA FILE OR THE OUTPUT FILES OF CRUMBLE AT THE SCOPE. YOU CAN DO THIS WITH THE INTERCOM COMMANDS (REFERENCE {INTERCOM}):

```
UNLOAD,OLDLFN<CR>
BATCH,OLDLFN,RENAME,NEWLFN<CR>
```

WHERE OLDLFN IS THE OLD LOGICAL FILE NAME, NEWLFN IS THE NEW LOGICAL FILE NAME, AND <CR> MEANS CARRIAGE RETURN.

7.3 USER INPUT

7.3.1 INTRODUCTION

INPUT IS HANDLED WITH DIRECTIVES AND DATA CARDS ASSOCIATED THEREWITH. INPUT DATA ARE FREE FORMAT, SEPARATED BY A COMMA OR BLANK(S). THERE ARE THREE TYPES OF DATA EXPECTED AS INPUT: INTEGER, REAL AND ALPHABETIC. INTEGER INPUT AND REAL INPUT FOLLOW THE USUAL FORTRAN CONVENTIONS, I.E. INTEGER IS ENTERED WITHOUT A DECIMAL POINT, REALS ARE ENTERED WITH A DECIMAL POINT (AND MAY BE IN EXPONENTIAL FORM). ALPHABETICS ARE USED FOR INPUTTING THE DIRECTIVES AND THE RELATIONS USED TO DEFINE THE FILTERS. THE DATA TYPES ARE INDICATED IN THE INPUT DESCRIPTIONS AS 'I' FOR INTEGER, 'R' FOR REAL, AND 'A' FOR ALPHABETIC.

FILTERING IS PERFORMED ON THE NODAL COORDINATES. ANY NODE WHICH HAS COORDINATES WHICH DO NOT PASS THRU THE USER DEFINED FILTERS ARE ELIMINATED.

7.3.2 DIRECTIVES IN 'DFLSIFT'

THE FOLLOWING DIRECTIVES ARE AVAILABLE:

PICTURE DEFINITION	DEFINE THE EXTENT OF THE PICTURE TO BE DRAWN.
UNROLL	UNROLL A SURFACE INTO 2D
XYZ FILTER	FILTER ELEMENTS PER COORDINATE DATA

DFLSIFT
'PICTURE DEFINITION' DIRECTIVE

7.3.2.1 PICTURE DEFINITION

PICTURE DEFINITION ALLOWS YOU TO DEFINE THE LIMITS OF YOUR DISPLAY AND HENCE 'ZOOM' IN ON AN AREA OF INTEREST. PICTURE DEFINITION IS A 2 CARD BLOCK.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'PICTURE DEFINITION'
(2)	CARD 2		
(3)	R	XLL	X COORDINATE OF THE LOWER LEFT CORNER OF THE PICTURE
	R	YLL	Y COORDINATE OF THE LOWER LEFT CORNER OF THE PICTURE
	R	XUR	X COORDINATE OF THE UPPER RIGHT CORNER OF THE PICTURE
	R	YUR	Y COORDINATE OF THE UPPER RIGHT CORNER OF THE PICTURE

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!

2. EACH ENTITY ON A CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).

3. IF THE 'UNROLL' DIRECTIVE IS USED SIMULTANEOUSLY WITH 'PICTURE DEFINITION',

DFLSIFT
'PICTURE DEFINITION' DIRECTIVE

SPECIFY THE PICTURE DEFINITION IN TERMS OF THE UNROLLED STRUCTURAL DIMENSIONS. THUS, IF A CYLINDER OF DIAMETER 10 IS UNROLLED ABOUT THE Y AXIS, THE RANGE OF X DIMENSIONS TO CONSIDER FOR PICTURE DEFINITION IS FROM 0 TO 31.415.

EXAMPLE: EXCLUDE FROM THE DISPLAY ALL THOSE NODES WHICH LIE OUTSIDE THE UNIT SQUARE.

SOLUTION: PROVIDE A PICTURE DEFINITION TO 'DFLSIFT' AS FOLLOWS:

```
PICTURE DEFINITION
0,0,1,1
```

7.3.2.2 UNROLL

UNROLL PERMITS YOU TO DISPLAY A SURFACE IN 2 DIMENSIONS BY UNROLLING IT ABOUT AN AXIS. DEFAULT IS NOT UNROLL, THAT IS, IF THE UNROLL DIRECTIVE IS NOT SELECTED, THE VIEW WILL BE A PROJECTED IMAGE. UNROLL IS A TWO CARD OPTION.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'UNROLL'
(2)	A	CARD	AXIS NAME OR NUMBER
	CARD 2		
(3)	R	X	FIRST COORDINATE OF UNROLLING CENTER
	R	Y	SECOND COORDINATE OF UNROLLING CENTER

NOTES:

1. ENTER THE WORD 'UNROLL' BEGINNING IN COLUMN 1.
2. PERMISSIBLE AXIS NAMES ARE 'X', 'Y', 'Z'. SYNONYMS ARE '1', '2', AND '3', RESPECTIVELY. THE AXIS NAMES ARE SEPARATED FROM THE DIRECTIVE BY A COMMA (,) OR ONE OR MORE BLANKS ( ).
3. THE COORDINATES OF UNROLLING CENTER ARE GIVEN IN THE ORDER X-Y, Y-Z, OR Z-X, DEPENDING ON THE AXIS SPECIFIED ON CARD 1.

DFLSIFT
'UNROLL' DIRECTIVE

EXAMPLE: UNROLL A CYLINDER LOCATED AT THE ORIGIN WITH ITS AXIS COINCIDENT WITH THE Z AXIS.

SOLUTION: USE THE FOLLOWING INPUT:

```
UNROLL Z
0.0,0.0
```

7.3.2.3 XYZ FILTER

XYZ FILTER PERMITS YOU TO EXCLUDE NODES FROM A DISPLAY WHICH DO NOT LIE WITHIN A REGION SPECIFIED BY COORDINATES OF THE GRIDPOINTS. XYZ FILTER IS A THREE CARD-TYPE SET. CARD 3 MAY BE REPEATED UP TO 20 TIMES, GIVING A MAXIMUM NUMBER OF DEFINABLE FILTERS OF 20.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'XYZ FILTER'
	CARD 2		
(2)	I	NXTESTS	NUMBER OF XYZ FILTER TESTS
(3)	CARD 3.1		
(4)	I	FLTRCRD	NUMBER OF THE COORDINATE TO BE FILTERED
(5)	A	XTSTREL	RELATIONAL SPECIFICATION
	R	XTEST	VALUE TO BE USED IN THE FILTER

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!

2. THE MAXIMUM NUMBER OF FILTERS IS 20.

3. REPEAT CARDS IN THIS SET UNTIL ALL THE REQUIRED

FILTERS HAVE BEEN DEFINED. EACH ENTITY ON A CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).

4. ANY OF THE COORDINATES MAY BE SPECIFIED IN A FILTER.

5. RELATIONS WHICH ARE TO BE USED IN THE FILTERS ARE LIMITED TO THE FOLLOWING VALID TWO CHARACTER ALPHABETIC ENTRIES:

EQ - EQUAL;
GE - GREATER THAN OR EQUAL TO;
GT - GREATER THAN;
LE - LESS THAN OR EQUAL TO;
LT - LESS THAN;
NE - NOT EQUAL TO.

EXAMPLE: PLOT ONLY THOSE COORDINATES WHICH LIE BETWEEN X COORDINATE 3.0 AND 15.0.

SOLUTION: ESTABLISH A 'DFLSIFT' FILTER AS FOLLOWS:

```
XYZ FILTER
2
3,GE,3.0
3,LE,15.0
```

7.4 EXECUTION

7.4.1 FROM BATCH...FIRST RUN:

```
JOBCARD,CM70000.
CHARGE,YOUR,GOBBLYGOOK.
COMMENT.----------------------------------------
COMMENT. PRODUCE FILE <NEWIN>.
COMMENT.----------------------------------------
ATTACH,WABS,ID=CSPR.
ATTACH,DATA,YOURDATA,ID=YOUR.
WABS.
UNLOAD,WABS,DATA.
COMMENT.----------------------------------------
COMMENT. ATTACH TAPE61, RESERVE PERM FILE
COMMENT. SPACE FOR OTHER FILES.
COMMENT.----------------------------------------
ATTACH,TAPE61,YOURTAPE61FROMSUBSTRC,ID=YOUR.
REQUEST,MSXYZ,*PF.
REQUEST,MSDISP,*PF.
REQUEST,DATA,*PF.
COMMENT.----------------------------------------
COMMENT. EXECUTE 'DFLSIFT', SAVE FILES
COMMENT.----------------------------------------
ATTACH,DFLSIFT,ID=CSPR.
DFLSIFT,,,NEWIN.
CATALOG,MSXYZ,YOURMSXYZANALYSISNAME,ID=YOUR.
CATALOG,MSDISP,YOURMSDISPANALYSISNAME,ID=YOUR.
CATALOG,DATA,YOURANALYSISNAMEPLOTDATA,ID=YOUR.
CATALOG,TAPE11,YOURANALYSISNAMETAPE11,ID=YOUR.
```

7.4.2 FROM BATCH...SUBSEQUENT RUNS:

```
JOBCARD,CM70000.
CHARGE,YOUR,GOBBLYGOOK.
COMMENT.----------------------------------------
COMMENT. ATTACH PERM FILES, REQUEST SPACE FOR
COMMENT. <DATA>
COMMENT.----------------------------------------
ATTACH,MSXYZ,YOURMSXYZANALYSISNAME,ID=YOUR.
```

DFLSIFT
EXECUTION

```
ATTACH,MSDISP,YOURMSDISPANALYSISNAME,ID=YOUR.
REQUEST,DATA,*PF.
COMMENT.----------------------------------------
COMMENT. EXECUTE 'DFLSIFT', SAVE FILES
COMMENT.----------------------------------------
ATTACH,DFLSIFT,ID=CSPR.
DFLSIFT,,,NEWIN.
CATALOG,DATA,YOURANALYSISNAMEPLOTDATA,ID=YOUR.
```

7.4.3 FROM TTY

NOT POSSIBLE BECAUSE 'DFLSIFT' TAKES TOO MUCH CM.

7.4.4 DEFAULT EXECUTE CARD

```
DFLSIFT,INPUT,OUTPUT,INFILE,DATA,TAPE61,DUMMY,MSDISP,
   DUMMY,MSXYZ.
```

7.5 LIMITATIONS AND REMARKS

1. LARGEST NUMERICAL MODEL: 2048 ELEMENTS AND 2048 NODES.

2. ELEMENT TYPES HANDLED: 8 (DOUBLY CURVED SHELL TRIANGLE) AND 20 (DOUBLY CURVED SHELL QUADRILATERAL).

3. MACHINE: CDC 6000 SERIES.

4. CENTRAL MEMORY: 70000 WORDS.

5. TIME ESTIMATE: ABOUT 5 NODES PER CPU SECOND.

6. PROGRAM MAINTENANCE: THE PROGRAM IS CURRENTLY BEING MAINTAINED BY THE AUTHOR. SOURCE CODE IS LOCATED IN THE UPDATE PROGRAM LIBRARY CSRODFLSIFTPL, ID=CSRO. COMPILED ROUTINES ARE IN THE PRELOAD LIBRARY CSRODFLSIFTPRE, ID=CSRO. ABSOLUTE (TASK LOADED) FILE IS DFLSIFT,ID=CSPR. COPIES OF THE FILES ARE MAINTAINED ON DISK DV4717.

7. PLACES FOR IMPROVEMENT: 'DFLSIFT' COULD BE EXTENDED TO HANDLE ALL THE ELEMENT TYPES IN THE 'SUBSTRC' LIBRARY.

7.6 FILE STRUCTURE

THE KNOWLEDGE OF THE FILE STRUCTURE USED BY 'DFLSIFT' IS NOT NECESSARY FOR ITS USE. HOWEVER, THIS KNOWLEDGE WOULD BE INVALUABLE TO SOMEONE WHO WISHED TO MODIFY THE PROGRAM. HENCE, THIS SECTION DESCRIBES THE MASS STORAGE RANDOM ACCESS FILES USED BY 'DFLSIFT'.

7.6.1 MSXYZ

MSXYZ IS THE MASS STORAGE COORDINATES FILE.

7.6.1.1 MAIN INDEX

THE MAIN INDEX IS NAMED XMASTER DIMENSIONED 5 WORDS

WORD ADDRESS TO:

1 TOTNODS(2) - THE TOTAL NUMBER OF NODES AND ELEMENTS
2 XLISTYP(TOTNODS) - A LIST OF THE TYPE OF ELEMENT TO WHICH THIS GRIDPOINT BELONGS
3 XYZXTM(18,2) - A LIST OF THE EXTREME VALUES OF COORDINATES FOR THIS ANALYSIS. NOTE THAT AN ANALYSIS WHICH USES SEVERAL KINDS OF ELEMENTS WILL PROBABLY HAVE MIXED UP EXTREME VALUES.
4 XYZNDX(2048) - THE SUBINDEX TO THE FILE

7.6.1.2 SUBINDEX

XYZNDX IS SET AS THE FILE SUBINDEX WITH A CALL TO STINDX. EACH ENTRY IS A POINTER TO THE COMPLETE SET OF COORDINATES FOR THE GRIDPOINT; E.G., XYZNDX(273) POINTS TO ALL THE COORDINATES ASSOCIATED WITH THE 273RD NODE (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

7.6.2 MSDISP

MSDISP IS THE MASS STORAGE DISPLACEMENT FILE.

7.6.2.1 MAIN INDEX

THE MAIN INDEX TO THE FILE IS NAMED DMASTER DIMENSIONED 5 WORDS.

WORD ADDRESS TO:

1 DISPNDX(2048) - THE FILE SUBINDEX
2 DISPXTM(13,2) - THE EXTREME DISPLACEMENT VALUES.
3 DPLOTS(13) - THE ARRAY WHICH TELLS WHICH (IF ANY) PLOTS ARE TO BE MADE.
IF DPLOTS(I) = 1, PLOT THIS DISPLACEMENT,
IF DPLOTS(I) = 0, DO NOT PLOT THIS DISPLACEMENT.
4 TOTNODS(2) - THE TOTAL NUMBER OF NODES AND ELEMENTS

7.6.2.2 SUBINDEX

DISPNDX IS SET BY A CALL TO STINDX. EACH CELL OF DISPNDX IS A POINTER TO THE SET OF DISPLACEMENTS FOR A NODE. THUS, FOR LIBRARY ELEMENT TYPE 8 FOR EXAMPLE, DISPNDX(456) POINTS TO A 9 * 1 ARRAY OF DISPLACEMENTS FOR THE 456TH NODE (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

7.7 REFERENCES

CCRM

"CONT" MANUAL

CHAPTER 8

PROCEDURES:

CYBER CONTROL LANGUAGE

(CCL)

PROCEDURES FOR THE

'SUBSTRC' USER

8.1 INTRODUCTION

THE CONTROL DATA CORPORATION NOS/BE CYBER CONTROL LANGUAGE (CCL) ALLOWS YOU TO MANIPULATE CONTROL STATEMENTS, AND WRITE CONTROL CARD "PROGRAMS". VARIOUS VERBS

- CAUSE CONTROL STATEMENTS TO BE SKIPPED OR PROCESSED CONDITIONALLY
- PROCESS AND REPROCESS A GROUP OF CONTROL STATEMENTS (I.E., LOOPS)
- MANIPULATE CCL SYMBOLIC NAMES
- CONTROL PROCESSING OF DIFFERENT GROUPS OF CONTROL CARDS (SUBROUTINES)

SEVERAL FUNCTIONS ARE PROVIDED FOR USE IN EXPRESSIONS, DATA MAY BE IMBEDDED IN PROCEDURES, AND A LIMITED ARITHMETIC CAPABILITY IS OFFERED.

CCL IS AN EXTREMELY POWERFUL TOOL FOR THE USER OF CDC COMPUTERS. THE CAPABILITY AVAILABLE THRU THE USE OF CCL IS CONSIDERABLE, AND INTERESTED READERS ARE DIRECTED TO CHAPTER 5 OF {NOS/BE} AND TO {DTNSRDC/CCL}.

THREE PROCEDURES HAVE BEEN WRITTEN WHICH SIMPLIFY THE USE OF 'SUBSTRC' AND ITS AUXILIARY PROGRAMS. THESE PROCEDURES: 'CRUMBLE', 'HOLD', AND 'RESTORE', ARE DESCRIBED IN THIS CHAPTER.

8.2 'CRUMBLE'

'CRUMBLE' IS A PROCEDURE USED IN CONJUNCTION WITH THE PROGRAMS 'DFLSIFT' AND 'STRSIFT'. IT BREAKS THE <DATA> FILES PRODUCED BY THESE PROGRAMS INTO CONVENIENT CHUNKS FOR VIEWING SPECIFIC DISPLACEMENTS OR STRESSES AT A TEKTRONIX DISPLAY TERMINAL.

8.2.1 EXECUTION

```
ATTACH,PROCFIL,CCLLIB,ID=CSRO.
ATTACH,DATA,YOURDATAFROMDFLSIFTORELSEWHERE,ID=YOUR.
BEGIN,CRUMBLE,PROCFIL,DATA,TAPE,N=7.
```

EACH ENTRY IN THE 'BEGIN' STATEMENT IS EXPLAINED AS FOLLOWS:

- BEGIN - START THE PROCEDURE
- CRUMBLE - PROCEDURE NAME TO BE STARTED
- PROCFIL - FILE ON WHICH THE PROCEDURE RESIDES
- DATA - NAME OF FILE TO BE CRUMBLED (DEFAULT NAME: DATA).
- TAPE - FIRST 4 CHARACTERS OF THE NAME OF EACH PIECE OF THE CRUMBLED FILE. (DEFAULT NAME: TAPE). NOTE THAT THE MAXIMUM NUMBER OF CHARACTERS IN THIS NAME IS 7.
- N=7 - HOW MANY PIECES ARE ON THE FILE <DATA> (DEFAULT NUMBER: 7)

AFTER THE EXECUTION OF THIS 'BEGIN', YOU WILL HAVE THE FOLLOWING 'LOCAL' FILES AT YOUR TERMINAL: PROCFIL, DATA, TAPE1, TAPE2, TAPE3, TAPE4, TAPE5, TAPE6, TAPE7. IF THE <DATA> FILE WAS INDEED PRODUCED BY 'DFLSIFT', THE <TAPEI> WILL CONTAIN THE DISPLACEMENTS FOR DEGREE OF FREEDOM I OF THE STRUCTURE. YOU MAY PROCESS THESE AS YOU WISH. TYPICALLY, YOU MIGHT WANT TO DRAW CONTOURS USING ONE OF THE CONTOUR PLOTTERS (E.G., 'CONT') AVAILABLE ON THE SYSTEM.

8.3 'HOLD'

'HOLD' WAS WRITTEN TO SIMPLIFY THE CATALOGING OF RESTART FILES AND TO FACILITATE THE USE OF A UNIFORM IDENTIFIER FOR ALL THE FILES ASSOCIATED WITH A NONLINEAR ANALYSIS.

'SUBSTRC' USES THE FILES <TAPE2>, <TAPE3>, <TAPE4>, AND <TAPE8> FOR RESTARTING A NONLINEAR ANALYSIS. IT ALSO PRODUCES <TAPE61> CONTAINING THE DISPLACEMENT VECTOR, AND <TAPE62> AND <TAPE63> CONTAINING THE STRESS VALUES FOR EACH LOAD INCREMENT. 'HOLD' PERMITS ALL OF THESE FILES TO BE SAVED WITH A SIMILAR PERMANENT FILE NAME FOR EASY IDENTIFICATION AND FOR SIMPLE PROCESSING BY THE PROCEDURE 'RESTART'. IT HANDLES ALL REQUESTS FOR PERMANENT FILE SPACE, SO YOU NEED NOT MAKE ANY SEPARATE REQUESTS FOR THIS.

NOTE THAT THE DTNSRDC CDC PERMANENT FILE SYSTEM PERMITS UP TO FIVE 'CYCLES' OF PERMANENT FILES WITH THE SAME NAME. THUS, THE SAME 'HOLD' STATEMENT IS USABLE A MAXIMUM OF FIVE TIMES. FURTHERMORE, YOU SHOULD OBSERVE THE SIZES OF THE FILES PRODUCED BY 'SUBSTRC' AND STORE THEM IN THE MOST ECONOMICAL PLACE WHEN THE ANALYSIS IS COMPLETE. THIS MAY BE MAGNETIC TAPE OR PRIVATE DISKPACK.

8.3.1 EXECUTION

'HOLD' IS EXECUTED AFTER THE ANALYSIS OF THE MATHEMATICAL MODEL BY 'SUBSTRC'.

```
JOB,...
CHARGE,...
ATTACH,NEWIN,YOURNEWINFILE,ID=YOUR.
ATTACH,SUBSTRC,ID=CSPR.
ATTACH,PROCFIL,CCLLIB,ID=CSRO.
SUBSTRC,NEWIN.
BEGIN,HOLD,PROCFIL,
     TITLELESSTHAN32CHARACTERS,ID=YOUR.
```

EACH ENTRY IN THE 'BEGIN' STATEMENT IS EXPLAINED AS FOLLOWS:

- BEGIN - START THE PROCEDURE

- HOLD - PROCEDURE NAME TO BE STARTED

- PROCFIL - FILE ON WHICH THE PROCEDURE RESIDES

- TITLELESSTHAN32CHARACTERS - A STRING OF UP TO 32 CHARACTERS DESCRIPTIVE OF THE ANALYSIS. ALL FILES CATALOGED BY 'HOLD' WILL HAVE THIS STRING AS THE PREFIX, AND THE STRINGS 'TAPE' AND 'XX' APPENDED AS THE PERMANENT FILE NAME. 'XX' IN THIS CASE IS THE NUMBER OF THE TAPE TO BE CATALOGED: EITHER 2, 3, 4, 8, 61, 62, OR 63. FOR EXAMPLE, THE STATEMENT AS WRITTEN ABOVE WOULD CATALOG THE FILES

  TITLELESSTHAN32CHARACTERSTAPE2
  TITLELESSTHAN32CHARACTERSTAPE3
  TITLELESSTHAN32CHARACTERSTAPE4
  TITLELESSTHAN32CHARACTERSTAPE8
  TITLELESSTHAN32CHARACTERSTAPE61
  TITLELESSTHAN32CHARACTERSTAPE62
  TITLELESSTHAN32CHARACTERSTAPE63

- ID=YOUR - ENTER YOUR USER IDENTIFIER

8.4 'RESTART'

'RESTART' WAS WRITTEN TO SIMPLIFY THE RESTART OF NONLINEAR 'SUBSTRC' ANALYSES, AND TO FACILITATE THE USE OF A UNIFORM IDENTIFIER FOR ALL OF THE FILES ASSOCIATED WITH A NONLINEAR ANALYSIS. 'RESTART' OBTAINS THE FILES <TAPE2>, <TAPE3>, <TAPE4> AND <TAPE8> NECESSARY FOR RESTARTING THE 'SUBSTRC' ANALYSIS THROUGH THE EXECUTION OF A SINGLE CONTROL CARD.

'RESTART' IS EXECUTED PRIOR TO THE RESTART ANALYSIS.

8.4.1 EXECUTION

```
JOB,...
CHARGE,...
ATTACH,PROCFIL,CCLLIB,ID=CSRO.
BEGIN,RESTART,PROCFIL,
     TITLELESSTHAN32CHARACTERS,ID=YOUR.
ATTACH,IN,YOURRESTARTINPUT,ID=YOUR.
ATTACH,SUBSTRC,ID=CSPR.
SUBSTRC,IN.
```

EACH ENTRY IN THE 'BEGIN' STATEMENT IS EXPLAINED AS FOLLOWS:

- BEGIN - START THE PROCEDURE
- RESTART - PROCEDURE NAME TO BE STARTED
- PROCFIL - FILE ON WHICH THE PROCEDURE RESIDES
- TITLELESSTHAN32CHARACTERS - A STRING OF UP TO 32 CHARACTERS DESCRIPTIVE OF THE ANALYSIS. THIS IS MOST EASILY OBTAINED FROM THE EXECUTION OF THE PROCEDURE 'HOLD' AFTER AN EARLIER ANALYSIS STEP. NOTE THAT THIS STRING MUST MATCH THE NAMES OF SOME PERMANENT FILES CATALOGED ON THE SYSTEM. FOR EXAMPLE, THE STATEMENT ABOVE WOULD ATTEMPT TO ATTACH THE FOLLOWING FILES:

```
TITLELESSTHAN32CHARACTERSTAPE2
TITLELESSTHAN32CHARACTERSTAPE3
TITLELESSTHAN32CHARACTERSTAPE4
TITLELESSTHAN32CHARACTERSTAPE8
```

- ID=YOUR - USER IDENTIFIER UNDER WHICH THE FILES HAVE BEEN CATALOGED. (DEFAULT ID: CSRO)

CHAPTER 9

"REVISE"

REVISE RESTART FILES

9.1 INTRODUCTION

'REVISE' WAS WRITTEN TO PERMIT YOU TO ALTER THE NEXT INCREMENT OF PRESSURE LOADING AND TO CHANGE THE DEGREE OF FREEDOM BEING MONITORED AS THE CONVERGENCE CRITERION.

THE PROGRAM 'SUBSTRC' SOLVES NON-LINEAR PROBLEMS IN AN INCREMENTAL FASHION. YOU PROVIDE A SCHEDULE OF LOAD FACTORS WHICH ARE APPLIED TO THE PREVIOUS LOAD FACTOR TO PRODUCE A TOTAL LOAD STATE ON THE MATHEMATICAL MODEL. ADDITIONALLY, THE DISPLACEMENT VECTOR FOR THE NEXT INCREMENT OF LOAD IS "GUESSED" BY LINEAR EXTRAPOLATION TO ATTEMPT TO REDUCE THE AMOUNT OF COMPUTING NECESSARY TO ATTAIN CONVERGENCE. 'REVISE' IS A FAST WAY TO MODIFY THE RESTART TAPE TO PRODUCE THE APPROPRIATE RESTART CONDITION. THIS MAY BE NECESSARY, FOR EXAMPLE, WHEN CONVERGENCE IS NOT ATTAINED AT A LOAD STEP, AND YOU WISH TO SUPPLY ONLY A FRACTION OF THE NEXT LOAD STEP. BEFORE 'REVISE' WAS WRITTEN, THE ENTIRE PREVIOUS ANALYSIS STEP IN 'SUBSTRC' HAD TO BE RUN TO PRODUCE THE PROPER RESTART TAPE.

CONVERGENCE TO AN EQUILIBRIUM POSITION AT SOME LOAD LEVEL IS DETERMINED BY THE DIFFERENCE BETWEEN THE DISPLACEMENTS OF THE STRUCTURE AFTER ITERATION I AND ITERATION I+1. THE MEASURE USED IS THE DISPLACEMENT OF SOME USER SPECIFIED NODE AND DEGREE OF FREEDOM (YOU ESSENTIALLY SPECIFY THE DEGREE OF FREEDOM AT WHICH THE INFINITY NORM OF THE DISPLACEMENT VECTOR OCCURS). DURING DEFORMATION OF THE STRUCTURE, THE DEGREE OF FREEDOM WHICH HAS THE LARGEST DISPLACMENT MAY CHANGE DUE TO THE ASSUMPTION OF DIFFERENT MODE SHAPES BY THE STRUCTURE. HENCE, IT MAY SOMETIMES BE NECESSARY FOR YOU TO CHANGE THE DEGREE OF FREEDOM BEING MONITORED FROM LOAD INCREMENT TO LOAD INCREMENT. 'REVISE' PERMITS THIS MODIFICATION, WHEREAS THE USE OF 'SUBSTRC' ALONE WOULD NOT.

'REVISE' FITS INTO A NONLINEAR ANALYSIS AS FOLLOWS:

1. PREPARE INPUT DATA FOR 'WABS'.

2. RUN 'WABS', SAVE FILE <NEWIN>.

3. RUN 'SUBSTRC', SAVE RESTART TAPES (SEE PROCEDURES 'HOLD' AND 'RESTART', CHAPTER 8).

4. EXAMINE 'SUBSTRC' OUTPUT FOR CONVERGENCE.

   IF ANALYSIS IS COMPLETE, STOP.

   IF THE LOAD STEP MUST BE MODIFIED, OR THE MONITORED NODE CHANGED, RUN 'REVISE', MODIFYING THE LAST FILE WRITTEN BY 'SUBSTRC' AS EITHER <TAPE3> OR <TAPE8>.

5. GO TO STEP 3.

'REVISE' IS WRITTEN IN 'RATIONAL FORTRAN' (RATFOR) AND IS MODULAR IN CONSTRUCTION. IT MAY THUS BE EASILY EXTENDED TO INCORPORATE OTHER FEATURES YOU MAY DESIRE.

'REVISE' IS TOO LARGE TO RUN AS AN INTERACTIVE JOB ON THE DTNSRDC CDC6000 COMPUTERS, AND MUST BE RUN AS A BATCH JOB.

9.2 FILES

THE FOLLOWING FILES ARE USED BY 'REVISE':

INPUT	USER INPUT.
OUTPUT	USER MESSAGES
OLDTAP	RESTART TAPE TO BE MODIFIED (EITHER <TAPE3> OR <TAPE8>)
NEWTAP	MODIFIED RESTART TAPE
ZZZXXX	SCRATCH FILE TO TEMPORARILY STORE SUBSTRUCTURE DISPLACEMENTS

9.3 EXECUTION

9.3.1 AS A BATCH JOB

TO RUN 'REVISE', ONE MAY EXECUTE THE FOLLOWING CONTROL CARDS:

```
JOB,CM77000,...
CHARGE,YOUR,GOBBLYGOOK.
ATTACH,OLDTAP,YOURRESTARTTAPE3OR8,ID=YOUR.
ATTACH,IN,YOURREVISEINPUTFILE,ID=YOUR.
ATTACH,REVISE,ID=CSPR.
REQUEST,NEWTAP,*PF.
REVISE,IN.
CATALOG,NEWTAP,YOURRESTARTTAPE3OR8REVISED,ID=YOUR.
```

9.3.2 INTERACTIVE

NOT POSSIBLE BECAUSE 'REVISE' IS TOO LARGE.

9.3.3 DEFAULT EXECUTION

THE DEFAULT EXECUTION OF 'REVISE' IS:

```
REVISE,INPUT,OUTPUT,OLDTAP,NEWTAP,ZZZXXX.
```

9.4 USER INPUT

THE 'REVISE' INPUT FILE IS MADE IN TWO PARTS: PART ONE DESCRIBES THE MODIFICATIONS NECESSARY TO <OLDTAP>, AND PART TWO IS COMPRISED OF THE INTERMEDIATE FILE <NEWIN> PRODUCED BY 'WABS'. THE TWO FILE PARTS ARE SEPARATED WITH A 7/8/9 CARD.

9.4.1 <INPUT> FILE, PART 1

INPUT DATA ARE FREE FORMAT, SEPARATED BY A COMMA OR BLANK(S). THERE ARE TWO TYPES OF DATA EXPECTED AS INPUT: INTEGER, AND REAL. AN INTEGER IS ENTERED WITHOUT A DECIMAL POINT. A REAL IS ENTERED WITH OR WITHOUT A DECIMAL POINT (AND MAY BE IN EXPONENTIAL FORM). THE DATA TYPES ARE INDICATED IN THE INPUT DESCRIPTIONS AS 'I' FOR INTEGER, AND 'R' FOR REAL.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1.1		
(2)	R	FACOLD	PRESSURE FACTOR IN PREVIOUS RUN
	R	FACNEW	PRESSURE FACTOR TO BE APPLIED

REVISE
<INPUT> FILE, PART 1

(3)	CARD 1.2		
(4)	I	NEWNOD	NEW NODE NUMBER TO BE MONITORED
	I	NEWDOF	DEGREE OF FREEDOM AT 'NEWNOD' TO BE MONITORED
	CARD 1.3		
(5)			7/8/9 CARD

NOTES:

1. THIS CARD IS ALWAYS REQUIRED.
2. 'SUBSTRC' INCREASES THE LOADING ON THE MATHEMATICAL MODEL IN INCREMENTS WHICH ARE OBTAINED FROM PREVIOUS PRESSURE LOADING INCREMENTS. FOR EXAMPLE, ASSUME THE LOADING SEQUENCE ON THE MODEL IS TO BE 1000, 2000, 3000 AND 4000 PSI. ASSUME FURTHER THAT THE INITIAL RUN WILL BE MADE THRU 3000 PSI, WITH A RESTART TAPE THEN READY TO EXECUTE A LOAD STEP OF 4000. THE INPUT DATA TO 'SUBSTRC' NECESSARY TO PRODUCE THIS LOADING HISTORY REQUIRES THAT THE INITIAL LOAD (1000 PSI) BE APPLIED IN THE APPROPRIATE SUBSTRUCTURES THRU THE USE OF EITHER DISTRIBUTED OR CONCENTRATED LOADS, AND THE FOLLOWING INPUT PROVIDED IN THE 'SUBSTRC' LOADING HISTORY BLOCK (SEE CHAPTER 13):

```
PROPORTIONAL INCREMENT
1.0
PROPORTIONAL INCREMENT
1.0
PROPORTIONAL INCREMENT
1.0
```

REVISE
<INPUT> FILE, PART 1

LETTING 'LOADI' INDICATE THE LOAD VALUE AT STEP I AND 'DELLOADI' AS THE LOAD INCREMENT FROM 'LOADI' TO 'LOADI+1', WE SHOW THAT 'SUBSTRC' USES VALUES OF 'FACTO' TO INCREASE THE LOAD LEVELS AS FOLLOWS:

```
LOAD1     = DELLOAD1 = 1000

LOAD2     = LOAD1 + (FACTO*DELLOAD1)
          = 1000  + ( 1.0*1000 )
          = 2000

DELLOAD2 = FACTO*DELLOAD1 = 1.0 * 1000 = 1000
LOAD3    = LOAD2 + DELLOAD2 = 2000 + 1000 = 3000

DELLOAD3 = FACTO*DELLOAD2 = 1.0 * 1000 = 1000
LOAD4    = LOAD3 + DELLOAD3 = 3000 + 1000 = 4000
```

ASSUME NOW THAT THE ANALYSIS HAS PROCEEDED UP THRU 3000 PSI AND THE RESTART TAPES ARE READY FOR ANALYSIS AT 4000 PSI. WE DETERMINE FROM AN EXAMINATION OF THE STRUCTURAL BEHAVIOR, HOWEVER, THAT WE WOULD RATHER PERFORM AN ANALYSIS AT 3500. THIS LOADING WOULD REQUIRE A 'FACTO' OF 0.5 RATHER THAN 1.0: THUS, 'FACOLD' IS ENTERED AS 1.0, AND 'FACNEW' IS ENTERED AS 0.5.

3. THIS CARD IS OPTIONAL. IF IT IS NOT DESIRABLE TO CHANGE THE MONITORED DEGREE OF FREEDOM, YOU SHOULD OMIT THIS CARD.

4. 'NEWNOD' MUST OCCUR IN THE FIRST SUBSTRUCTURE.

5. THE SYMBOL '7/8/9' MEANS THAT A 7, AN 8 AND A 9 ARE PUNCHED IN THE SAME CARD COLUMN (USING THE MULTIPUNCH FEATURE OF THE KEYPUNCH MACHINE). 7/8/9 IS PUNCHED IN COLUMN 1 TO PROVIDE THE NECESSARY <INPUT> FILE PART SEPARATOR.

   IT IS PROBABLY EASIEST TO COMPOSE THE <INPUT> FILE FROM AN INTERACTIVE TERMINAL USING ONE OF THE SYSTEM EDITORS. IF YOU USE 'NETED', THE 7/8/9 CARD IS REPRESENTED BY THE 3 CHARACTERS 'EOF' TYPED BEGINNING IN COLUMN 1 OF A LINE. IF YOU USE 'EDITOR' (NOT RECOMMENDED), THE 7/8/9 CARD IS REPRESENTED BY THE 4 CHARACTERS '*EOF' TYPED BEGINNING IN COLUMN 1 OF A LINE.

9.4.2 <INPUT> FILE, PART 2

PART 2 OF THE <INPUT> FILE IS COMPRISED OF THE FIRST 9 CARDS OF THE 'WABS' INTERMEDIATE FILE <NEWIN>. USING ONE OF THE SYSTEM EDITORS, THESE CARDS MAY EASILY BE APPENDED TO PART 1 OF THE <INPUT> FILE AND SAVED. VALUES WHICH APPEAR IN THE OUTPUT OF THE PREVIOUS ANALYSIS WITH 'SUBSTRC' SHOULD BE USED HERE. BRIEFLY, WITH NO FURTHER EXPLANATION OF THESE DATA, WE PRESENT THE CONTENTS OF THESE CARDS. NOTE THAT THIS FILE IS NOT (THAT IS: NOT!) FREE FORMAT. ALL NUMBERS ARE INTEGERS (WITH THE EXCEPTION OF THE FIRST CARD) AND MUST BE ENTERED RIGHT JUSTIFIED IN THE FIELDS SPECIFIED. IN THE DESCRIPTION BELOW, THE DATA TYPE NOW REFERS TO THE COLUMNS WHICH THE DATA ARE TO OCCUPY.

NOTES	DATA TYPE	VAPIABLE	
	CARD 2.1		
	1-76	LABEL	76 COLUMNS OF TITLE
	CARD 2.2		
	1-10	MAXALL	SIZE OF COMMON /SPACE/
	11-15	IDIM	GO/NOGO SWITCH
	16-20	IRD1	LENGTH OF INDEX FOR <TAPE12>
	21-25	IRD2	LENGTH OF INDEX FOR <TAPE14>
	26-30	INEW	FLAG FOR NEW ITERATIVE PROCEDURE

REVISE
<INPUT> FILE, PART 2

CARD 2.3

1-5	NELTYP	NUMBER OF ELEMENT TYPES
6-10	J1	ELEMENT TYPE 1
11-15	J2	ELEMENT TYPE 2
16-20	J3	ELEMENT TYPE 3

CARD 2.4

1-5	ISI	FLAG FOR LARGE DISPLACEMENT ANALYSIS
6-10	IRESID	NOT USED
11-15	KINHRD	FLAG FOR KINEMATIC HARDENING
16-20	LODCOR	FLAG FOR LOAD CORRECTION

CARD 2.5

1-5	ICRT	MATRIX SOLUTION FLAG
6-10	MAXNP	MAXIMUM NODAL CONNECTIVITY
11-15	MAXBW	MAXIMUM NODAL BANDWIDTH/2
16-20	MXPD	NUMBER OF IN-STORE ROWS OF STIFFNESS MATRIX
21-25	IELAS	ELASTIC STORAGE FLAG
26-30	IPRBLD	FLAG FOR BUILDING SUBSTRUCTURE TAPE
31-35	ITIEM	NUMBER OF TIES
36-40	ISTYPM	NUMBER OF TYPES OF TIES

REVISE
<INPUT> FILE, PART 2

41-45	LONGTM	NUMBER OF RETAINED NODES PLUS 1
46-50	NUMDIS	NUMBER OF TYPES OF DISTRIBUTED LOADS

CARD 2.6

1-5	MESHR	INPUT TAPE NUMBER
6-10	IPLOT	NOT USED
11-15	IRSTRT	NOT USED
16-20	IELSTO	ELEMENT STORAGE FLAG
21-25	IDEV	DEBUGGING SWITCH
26-30	IFULL	NOT USED
31-35	IOFF	STRESS PRINTOUT FLAG
36-40	IBUILD	BUILD SUBSTRUCTURE TAPE FLAG
41-45	ICUR	BUILD SUBSTRUCTURE TAPE FLAG
46-50	DEPOACH	DEBUGGING SWITCH

CARD 2.7

1-5	NUMEL	MAXIMUM ELEMENTS IN A SUBSTRUCTURE
6-10	NUMNP	MAXIMUM NODES IN A SUBSTRUCTURE
11-15	NUMBC	MAXIMUM BOUNDARY CONDITIONS IN A SUBSTRUCTURE
16-20	NSTRES	STRESS LOCATION FLAG
21-25	DUMMY	NOT USED

REVISE
<INPUT> FILE, PART 2

26-30	NBCTMX	MAXIMUM BOUNDARY CONDITION TRANSFORMATIONS IN A SUBSTRUCTURE
31-35	MPTPMX	MAXIMUM TRANSFORMATIONS IN A SUBSTRUCTURE

CARD 2.8

1-5	MPRMAX	MAXIMUM PRESSURE LOADS IN A SUBSTRUCTURE
6-10	NPIMAX	MAXIMUM INTERNAL NODES IN A SUBSTRUCTURE
11-15	NPBMAX	MAXIMUM NODES ON A SUBSTRUCTURE EDGE
16-20	NUMMAX	MAXIMUM NODES IN A SUBSTRUCTURE
21-25	NSTCON	NUMBER OF SUBSTRUCTURES
26-30	NTPBO	TOTAL NODES ON EDGES
31-35	NNIMIN	MINIMUM NUMBER OF INTERNAL NODES IN A SUBSTRUCTURE
36-40	MAXBWO	MAXIMUM HALF-BANDWIDTH OF INTERSUBSTRUCTURE CONNECTIVITY
41-45	ISUBXP	MATRIX SOLUTION FLAG
46-50	ITEN	NOT USED

REVISE
<INPUT> FILE, PART 2

CARD 2.9

1-5	MASTRS	MATRIX SOLUTION FLAG
6-10	LASTRS	SUBSTRUCTURE RESTART FLAG
11-15	Q	NUMBER OF RESTART TAPE
16-20	O	NUMBER OF RESTART TAPE
21-25	IPROV	MATRIX SOLUTION FLAG
26-30	ISUBPR	PRINT SUPPRESSION FLAG
31-35	JEL1	NONLINEAR SOLUTION FLAG

9.5 LIMITATIONS AND REMARKS

1. IT WOULD BE INSTRUCTIVE TO READ THE 'REVISE' PROGRAM TO APPRECIATE THE 'SUBSTRC' RESTART FILE STRUCTURE.

2. MINIMUM FIELD LENGTH TO EXECUTE 'REVISE': APPROXIMATELY 65000 WORDS.

3. MACHINE: CDC 6000

4. TIME ESTIMATE: 0.1 SECOND PER ELEMENT

5. PROGRAM MAINTENANCE: 'REVISE' IS WRITTEN IN RATIONAL FORTRAN AND IS MAINTAINED BY THE AUTHOR. THE SOURCE CODE IS LOCATED IN THE UPDATE LIBRARY REVISEPL ,ID=CSRO. THE RELOCATABLE LIBRARY IS LOCATED IN THE EDITLIB LIBRARY REVISELIB ,ID=CSRO. THE UPDATE LIBRARY, THE EDITLIB LIBRARY, AND THE ABSOLUTE EXECUTABLE CODE IS ALSO MAINTAINED ON THE PRIVATE DISK DV4717 AT THE DTNSRDC CDC6400.

CHAPTER 10

'SHELLX'

PRODUCE SHELL ELEMENT COORDINATES

10.1 INTRODUCTION

'SHELLX' WAS WRITTEN TO ASSIST IN THE PREPARATION OF COORDINATE DATA FOR THE ISOPARAMETRIC SHELL ELEMENTS IN THE 'MARC' PROGRAMS. THE GEOMETRIC DEFINITION AND THE DISPLACEMENT FUNCTION FOR SHELL ELEMENTS 8 (DUPUIS TRIANGLE) AND 20 (JONES QUADRILATERAL) ARE WRITTEN IN TERMS OF TWO COORDINATES WHICH MEASURE SOME PARAMETER INTRINSIC TO THE SURFACE, THREE COORDINATES WHICH DEFINE THE POSITION OF THE NODE IN SPACE, AND SIX OTHER COORDINATES WHICH DESCRIBE THE GEOMETRY OF THE SHELL SURFACE IN TERMS OF DERIVATIVES. THERE ARE THEREFORE A TOTAL OF ELEVEN COORDINATES REQUIRED FOR EACH SHELL NODE. BECAUSE OF THE RATHER LARGE NUMBER OF COORDINATES REQUIRED FOR THESE ELEMENTS 'SHELLX' SHORTENS THE TIME NECESSARY TO PREPARE THIS DATA AND ENSURES THAT IT IS EXPRESSED IN THE PROPER TERMS.

'SHELLX' IS WRITTEN IN 'RATIONAL FORTRAN' (RATFOR) AND IS MODULAR IN CONSTRUCTION. IT IS QUITE EASY TO MODIFY, SHOULD ADDITIONAL SURFACE REPRESENTATIONS BE REQUIRED IN THE FUTURE.

'SHELLX' WAS DESIGNED TO BE RUN FROM AN INTERACTIVE TERMINAL IN A 'REMOTE BATCH' MODE, BUT IT WILL ALSO RUN AS A BATCH JOB. INPUT DATA ARE, FOR THE MOST PART, FREE FORMAT.

10.2 FILES

THE FOLLOWING FILES ARE USED BY 'SHELLX':

A	USER INPUT. THIS FILE IS NOT REWOUND.
B	CONTAINS THE 11 COORDINATES NEEDED FOR EACH NODE. REWOUND BEFORE AND AFTER EXECUTION.
OUTPUT	PRINTED OUTPUT

10.3 USER INPUT

INPUT IS HANDLED WITH DIRECTIVES AND DATA CARDS ASSOCIATED THEREWITH. INPUT DATA ARE FREE FORMAT, SEPARATED BY A COMMA OR BLANK(S). THERE ARE THREE TYPES OF DATA EXPECTED AS INPUT: INTEGER, REAL AND ALPHABETIC. AN INTEGER IS ENTERED WITHOUT A DECIMAL POINT, A REAL IS ENTERED WITH OR WITHOUT A DECIMAL POINT (AND MAY BE IN EXPONENTIAL FORM). ALPHABETICS ARE USED FOR INPUTTING THE DIRECTIVES. THE DATA TYPES ARE INDICATED IN THE INPUT DESCRIPTIONS AS 'I' FOR INTEGER, 'R' FOR REAL, AND 'A' FOR ALPHABETIC.

INPUT DATA ARE THE LEAST POSSIBLE REQUIRED TO COMPLETELY DEFINE THE SURFACE. NOTE, HOWEVER, THAT A BLANK IS NOT THE SAME AS A ZERO!

10.3.1 FORMAT OF THE FILE <A>

THE INPUT FILE <A> CONTAINS DIRECTIVES AND INPUT DATA IN THIS ORDER:

1. THE 'OLD' DIRECTIVE, IF DESIRED. OTHERWISE, OMIT THIS CARD.

2. THE 'ORIGIN' DIRECTIVE AND ITS ASSOCIATED DATA. IF THE ORIGIN OF YOUR SURFACE COINCIDES WITH THE GLOBAL ORIGIN, OMIT THIS SET OF DATA COMPLETELY.

3. ONE OF THE SURFACE MAPPING DIRECTIVES, FOLLOWED BY ITS ASSOCIATED DATA CARDS.

4. AN END-OF-RECORD (7/8/9 CARD) TO CONCLUDE THE DATA

10.3.2 DIRECTIVES

THE FOLLOWING DIRECTIVES ARE AVAILABLE IN 'SHELLX':

AXISYM	MAP COORDINATES TO AN AXISYMMETRIC SURFACE
CPLATE	MAP COORDINATES TO A PLATE DESCRIBED IN A CARTESIAN (RECTANGULAR) COORDINATE SYSTEM
CYLINDER	MAP COORDINATES TO A CIRCULAR CYLINDER
GENERALCYL	MAP COORDINATES TO A CYLINDER OF GENFRAL CROSS SECTION
MODESHAPE	MAP COORDINATES TO AN OUT-OF-ROUND CYLINDER
OLD	PRODUCE FILE <B> IN THE 'OLD' FORMAT.
ORIGIN	SET THE ORIGIN OF THE COORDINATE SYSTEM OTHER THAN 0,0,0.
PPLATE	MAP COORDINATES TO A PLATE USING A POLAR COORDINATE SYSTEM
TORUS	MAP COORDINATES TO A TORUS
ZOFXY	MAP COORDINATES TO A SURFACE GIVEN IN THE FORM Z=Z(X,Y)

10.3.3 THE OLD DIRECTIVE

THERE ARE 2 FORMATS AVAILABLE FOR OUTPUT FROM 'SHELLX'. THE 'NEW' FORMAT IS COMPATIBLE WITH THE PREPROCESSING PROGRAM 'WABS', AND HAS THE FORTRAN FORMAT (I5,7F10.5/4F10.5). THE 'OLD' FORMAT, WHICH IS COMPATIBLE WITH THE INTERMEDIATE FILE <NEWIN>, HAS THE FORTRAN FORMAT (I5,6F10.5/5F10.5). THE DEFAULT FORMAT IS 'NEW', AND IS AUTOMATICALLY PROVIDED. IF YOU WISH DATA IN THE 'OLD' FORMAT, (WHICH IS THEREFORE COMPATIBLE WITH 'MARCCDC' AND 'TRAINS'), YOU MUST INPUT THE 'OLD' DIRECTIVE AS THE FIRST CARD ON FILE <A>. OTHERWISE, OMIT IT ENTIRELY.

THIS IS A ONE CARD DATA BLOCK.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	WORD	'OLD'

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

10.3.4 THE ORIGIN DIRECTIVE

IT IS NOT ALWAYS CONVENIENT TO DESCRIBE THE GEOMETRY OF A SURFACE IN TERMS OF A GLOBAL COORDINATE SYSTEM. IT MAY BE MORE CONVENIENT TO DESCRIBE SURFACE GEOMETRY IN A LOCAL SYSTEM AND THEN TRANSLATE AND ROTATE THE LOCALLY DEFINED COORDINATES INTO THE GLOBAL SYSTEM. THE 'ORIGIN' DIRECTIVE PERMITS THIS RE-ORIENTATION THROUGH THE DEFINITION OF 3 POINTS IN THE LOCAL SYSTEM. POINT P0 IS THE LOCAL ORIGIN, POINT P1 IS A POINT ON THE LOCAL X-AXIS, AND POINT P2 IS A POINT IN THE LOCAL X-Y PLANE.

IF NO REORIENTATION OF YOUR SURFACE IS DESIRED, YOU MAY OMIT THIS ENTIRE SECTION.

THERE ARE A TOTAL OF 4 CARDS IN THIS DATA BLOCK.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	WORD	'ORIGIN'
(2)	CARD 2.1		
(3)	R	X0	X COORDINATE OF P0 (LOCAL ORIGIN)
	R	Y0	Y COORDINATE OF P0
	R	Z0	Z COORDINATE OF P0

(2)	CARD 2.2		
(4)	R	X1	THE X COORDINATE OF POINT P1 (ON THE LOCAL X AXIS)
	R	Y1	THE Y COORDINATE OF P1
	R	Z1	THE Z COORDINATE OF P1
(2)	CARD 2.3		
(5)	R	X2	THE X COORDINATE OF P2 (A POINT IN THE LOCAL X-Y PLANE)
	R	Y2	THE Y COORDINATE OF P2
	R	Z2	THE Z COORDINATE OF P2

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.
2. PUT 3 NUMBERS ON THIS CARD. A BLANK IS NOT THE SAME AS A ZERO!
3. THESE 3 COORDINATES DEFINING POINT P0 ARE USED TO FORM THE OFFSET VECTOR {OFFSET} OF THE LOCAL SYSTEM FROM THE GLOBAL ORIGIN.
4. THESE 3 COORDINATES DEFINING POINT P1 ARE USED TO DETERMINE A UNIT VECTOR {VX} IN THE DIRECTION OF THE LOCAL X-AXIS. POINT P1 MUST THEREFORE NOT BE COINCIDENT WITH THE LOCAL ORIGIN (P0).
5. THESE 3 COORDINATES DEFINING P2 ARE USED TO DETERMINE A UNIT VECTOR {VY} LYING IN THE LOCAL X-Y PLANE. {VX} IS THEN CROSSED WITH {VY} TO PRODUCE {VZ} NORMAL TO THE X-Y PLANE. FINALLY,

{VZ} IS CROSSED WITH {VX} TO (RE)PRODUCE {VY}. THIS ENSURES A MUTUALLY ORTHOGONAL TRIAD OF UNIT VECTORS (AND HENCE, DIRECTION COSINES) TO BE USED TO ROTATE THE LOCAL SURFACE INTO GLOBAL COORDINATES.

10.3.4.1 MAPPING DIRECTIVE 'AXISYM'

THIS DIRECTIVE MAPS THE INPUT COORDINATES TO AN AXISYMMETRIC SURFACE AS SHOWN IN FIGURE 10.1.

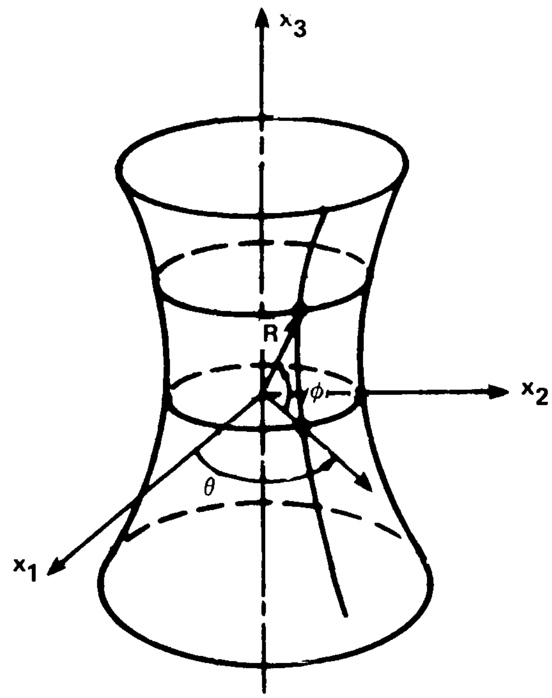

Figure 10.1 - Axisymmetric Shell

CAUTION!

THIS MAPPING IS NOT SURFACE MEASURING!

WHEN THE COORDINATES PROVIDED FOR ELEMENTS 8 AND 20 ARE DISTANCE MEASURING COORDINATES AND ARE ORTHOGONAL IN THE SHELL MIDDLE SURFACE, THEN THE COMPONENTS OF STRAIN PRODUCED BY THE ANALYSIS PROGRAM 'SUBSTRC' ARE THE PHYSICAL STRAIN COMPONENTS. THESE STRAINS CAN BE COMPARED WITH, SAY, STRAIN GAGE DATA. ON THE OTHER HAND, IF THE COORDINATES ARE NOT SURFACE DISTANCE

MEASURING BUT ARE SOME OTHER PARAMETER (E.G., RADIANS), THEN THE ANALYSIS PROGRAM PRODUCES THE COVARIANT COMPONENT OF STRAIN. IN ORDER TO COMPARE THIS QUANTITY WITH DIRECT STRAIN MEASUREMENT, THE COVARIANT COMPONENTS MUST BE CONVERTED TO DIRECT STRAIN MEASURE THROUGH THE USE OF THE METRICS OF THE SURFACE. A DISCUSSION OF CONVERTING COVARIANT STRAIN COMPONENTS TO PHYSICAL COMPONENTS IS CONTAINED IN (FUNG).

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'AXISYM'
(2)	CARD 1.2		
	I	NODE	GRIDPOINT NUMBER
	R	ANGLE	THETA, DEGREES
	R	ANGLE	PHI, DEGREES
	R	RADIUS	'R'
	R	DERIVATIVE	D(R)/D(PHI)

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER FIVE VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

SHELLX
SURFACE MAPPING DIRECTIVE 'AXISYM'

```
1 0 0 10.0 0.06
2 10 0
3 20 0
4 0 10
5 10 10
6 20 20 15.0
7 30 20
```

THIS SET OF DATA WOULD MAP ALL NODES USING D(R)/D(PHI) = 0.06, NODES 1 THROUGH 5 WITH R = 10.0, AND NODES 6 THROUGH 7 WITH R = 15.0.

10.3.4.2 MAPPING DIRECTIVE 'CPLATE'

THIS DIRECTIVE MAPS COORDINATES TO A FLAT PLATE IN A RECTANGULAR CARTESIAN COORDINATE SYSTEM. THE DEFAULT PLATE LOCATION IS THE GLOBAL X-Y PLANE. THIS MAPPING IS A SURFACE MEASURING MAPPING.

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'CPLATE'
(2)	CARD 1.2		
	I	NODE	GRIDPOINT NUMBER
	R	X	X COORDINATE OF THE NODE
	R	Y	Y COORDINATE OF THE NODE

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.
2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER THREE VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

SHELLX
SURFACE MAPPING DIRECTIVE 'CPLATE'

```
1 0 0
2 10
3 20
4 0 10
5 10
6 20
7 30
```

THIS SET OF DATA WOULD MAP NODES 1, 2, AND 3 TO THE POINTS (0,0), (10,0), AND (20,0) RESPECTIVELY. SIMILARLY, NODES 4 THROUGH 7 WOULD BE MAPPED TO (0,10), (10,10), (20,10), AND (30,10).

SHELLX
SUPFACE MAPPING DIRECTIVE 'CYLINDER'

10.3.4.3 MAPPING DIRECTIVE 'CYLINDER'

THIS DIRECTIVE MAPS COORDINATES TO A CIRCULAR CYLINDER. REFER TO FIGURE 10.2.

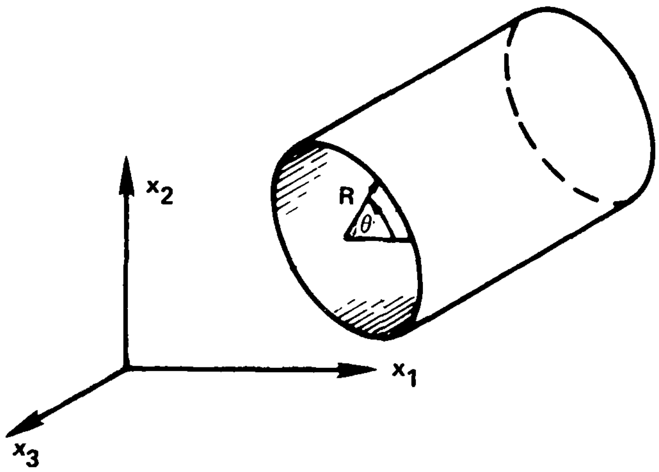

Figure 10.2 - Circular Cylinder

THIS MAPPING IS A SURFACE MEASURING MAPPING.

```
      DATA
NOTES TYPE  VAPIABLF


       CARD  1.1

 (1)    A   WOPD                    'CYLINDER'
```

SHELLX
SURFACE MAPPING DIRECTIVE 'CYLINDER'

(2) CARD 1.2

I	NODE	GRIPOINT NUMBER
R	ANGLE	ANGULAR COORDINATE OF NODE (DEGREES)
R	Z	LONGITUDINAL COORDINATE
R	RADIUS	CYLINDRICAL RADIUS

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.
2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER FOUR VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

SHELLX
SURFACE MAPPING DIRECTIVE 'CYLINDER'

```
1 0 0 10.0
2 10
3 20
4 0 10
5 10
6 20
7 30
```

THIS SET OF DATA WOULD MAP ALL NODES WITH A RADIUS = 10.0. NODES 1, 2, AND 3 WOULD BE MAPPED WITH Z = 0.0, AND NODES 4 THROUGH 7 WOULD BE MAPPED WITH Z = 10.0.

10.3.4.4 MAPPING DIRECTIVE 'GENERALCYL'

THIS DIRECTIVE MAPS COORDINATES TO A CYLINDER OF GENERAL CROSS SECTION. SEE FIGURE 10.3.

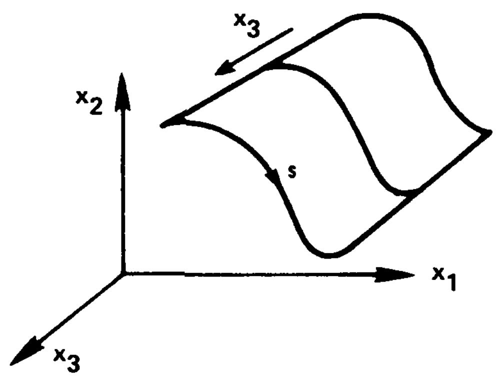

Figure 10.3 - General Cylinder

THIS MAPPING IS A SURFACE MEASURING MAPPING.

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'GENERALCYL'

(2) CARD 1.2

I	NODE	GRIDPOINT NUMBER
R	S	MERIDIONAL ARC LENGTH
R	Z	LONGITUDINAL COORDINATE
R	X	X COORDINATE OF NODE
R	Y	Y COORDINATE OF NODE
R	DERIVATIVE	DX/DS
R	DEPIVATIVE	DY/DS

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER SEVEN VALUES ON THE FIRST CAPD OF A SET, AND FEWER ON FOLLOWING CAPDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

```
10 0 0 0 0 0 0
20 0 5.0
30 0 10.0
```

THIS SET OF DATA WOULD MAP NODES 10, 20, AND 30 TO THE LOCATIONS OF 'Z' = 0, 5, AND 10, PESPECTIVELY.

10.3.4.5 MAPPING DIRECTIVE 'MODESHAPE'

THIS DIRECTIVE MAPS COORDINATES TO A CYLINDER WHOSE CROSS SECTION IS DEFINED BY A COSINE FUNCTION:

R = R' - DEL * COS (N * THETA)

WHERE:

R = RADIUS TO THE NODE
R' = THE MEAN RADIUS OF THE CYLINDER
DEL = AMPLITUDE OF THE IMPOSED MODE SHAPE
N = NUMBER OF CIRCUMFERENTIAL WAVES
THETA = ANGULAR COORDINATE OF THE NODE

THIS MAPPING IS AN EXTENSION OF THE 'CYLINDER' MAPPING, AND IS A SURFACE MEASURING MAPPING.

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'MODESHAPE'
(2)	CARD 1.2		
	I	NODE	GRIDPOINT NUMBER
	R	ANGLE	ANGULAR COORDINATE OF NODE (DEGREES)
	R	Z	LONGITUDINAL COORDINATE
	R	R'	MEAN RADIUS OF THE CYLINDER
	R	DEL	AMPLITUDE OF THE MODE SHAPE

SHELLX
SURFACE MAPPING DIRECTIVE 'MODESHAPE'

(3) I N NUMBER OF WAVES

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER FIVE VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

```
1 0 0 100.0 0.01 3
3 10
5 20
2 0 20.0
4 10
6 20
```

THIS SET OF DATA WOULD MAP ALL NODES TO A CYLINDER OF MEAN RADIUS R' = 100.0, AN AMPLITUDE OF MODE SHAPE = 0.01, AND A MODE SHAPE = 3. NODES 1, 3, AND 5 ARE MAPPED WITH A Z = 0, AND NODES 2, 4 AND 6 ARE MAPPED WITH A Z = 20.

3. BECAUSE 'SHELLX' READS INPUT IN FREE FORMAT, IT TREATS ALL ENTITIES FOLLOWING THE NODE NUMBER AS REALS. THUS, 'N' AS USED IN THE PROGRAM IS TREATED AS A REAL. IT IS THEREFORE POSSIBLE TO INPUT 'N' WITH A FRACTIONAL PART; THE MEANING OF THIS KIND OF INPUT IS NOT CLEAR, HOWEVER.

10.3.4.6 MAPPING DIRECTIVE 'PPLATE'

THIS DIRECTIVE MAPS COORDINATES TO A PLATE DESCRIBED IN POLAR COORDINATES. THE LOCATION OF THE PLANE OF THE PLATE IS SPECIFIED BY THE THIRD COORDINATE.

CAUTION!

THIS MAPPING IS NOT SURFACE MEASURING!

WHEN THE COORDINATES PROVIDED FOR ELEMENTS 8 AND 20 ARE DISTANCE MEASURING COORDINATES AND ARE ORTHOGONAL IN THE SHELL MIDDLE SURFACE, THEN THE COMPONENTS OF STRAIN PRODUCED BY THE ANALYSIS PROGRAM 'SUBSTRC' ARE THE PHYSICAL STRAIN COMPONENTS. THESE STRAINS CAN BE COMPARED WITH, SAY, STRAIN GAGE DATA. ON THE OTHER HAND, IF THE COORDINATES ARE NOT SURFACE DISTANCE MEASURING BUT ARE SOME OTHER PARAMETER (E.G., RADIANS), THEN THE ANALYSIS PROGRAM PRODUCES THE COVARIANT COMPONENT OF STRAIN. IN ORDER TO COMPARE THIS QUANTITY WITH DIRECT STRAIN MEASUREMENT, THE COVARIANT COMPONENTS MUST BE CONVERTED TO DIRECT STRAIN MEASURE THROUGH THE USE OF THE METRICS OF THE SURFACE. A DISCUSSION OF CONVERTING COVARIANT STRAIN COMPONENTS TO PHYSICAL COMPONENTS IS CONTAINED IN (FUNG).

SHELLX
SURFACE MAPPING DIRECTIVE 'PPLATE'

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'PPLATE'
(2)	CARD 1.2		
	I	NODE	GRIDPOINT NUMBER
	R	ANGLE	ANGULAR COORDINATE OF NODE (DEGREES)
	R	RADIUS	RADIAL COORDINATE OF THE NODE
	R	Z	LOCATION OF THE PLANE OF THE PLATE (DEFAULT = 0)

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER FOUR VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

```
1 0 5 10.0
2 10
3 20
4 0 10
5 10
6 20
7 30
```

SHELLX
SURFACE MAPPING DIRECTIVE 'PPLATE'

THIS SET OF DATA WOULD MAP ALL NODES TO PLATE LOCATED AT Z = 10.0. NODES 1 THROUGH 3 WOULD BE MAPPED WITH A RADIUS R = 5.0, AND NODES 4 THROUGH 7 WOULD BE MAPPED WITH A RADIUS R = 10.0.

10.3.4.7 MAPPING DIRECTIVE 'TORUS'

THIS DIRECTIVE MAPS COORDINATES TO A TORUS. REFERRING TO FIGURE 10.4, THE MIDDLE SURFACE OF THE SHELL IS DEFINED BY:

```
X = SR*COS(THETA)
Y = SR*SIN(THETA)*COS(PHI) + LR*(1 - COS(PHI))
Z = (LR - SR*SIN(THETA))*SIN(PHI)
```

WHERE:

SR = THE SMALL RADIUS
LR = THE LARGE RADIUS
THETA AND PHI ARE SHOWN IN THE FIGURE.

THIS MAPPING IS A SURFACE MEASURING MAPPING.

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'TORUS'
(2)	CARD 1.2		
	I	NODE	GRIDPOINT NUMBER
	R	THETA	ANGULAR COORDINATE, DEGREES
	R	PHI	ANGULAR COORDINATE, DEGREES
	R	SR	SMALL RADIUS OF THE TORUS
	R	LR	LARGE RADIUS OF THE TORUS

SHELLX
SURFACE MAPPING DIRECTIVE 'TORUS'

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER FIVE VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. FOR EXAMPLE:

```
1 0 0 10.0 100.0
2 10
3 20
4 0 10
5 10
6 20
7 30
```

THIS SET OF DATA WOULD MAP ALL COORDINATES TO A TORUS WITH LARGE RADIUS LR = 100.0 AND A SMALL RADIUS SR = 10.0. NODES 1 THROUGH 3 WOULD BE MAPPED WITH A 'PHI' OF 0, AND NODES 4 THROUGH 7 WOULD BE MAPPED WITH A 'PHI' OF 10.

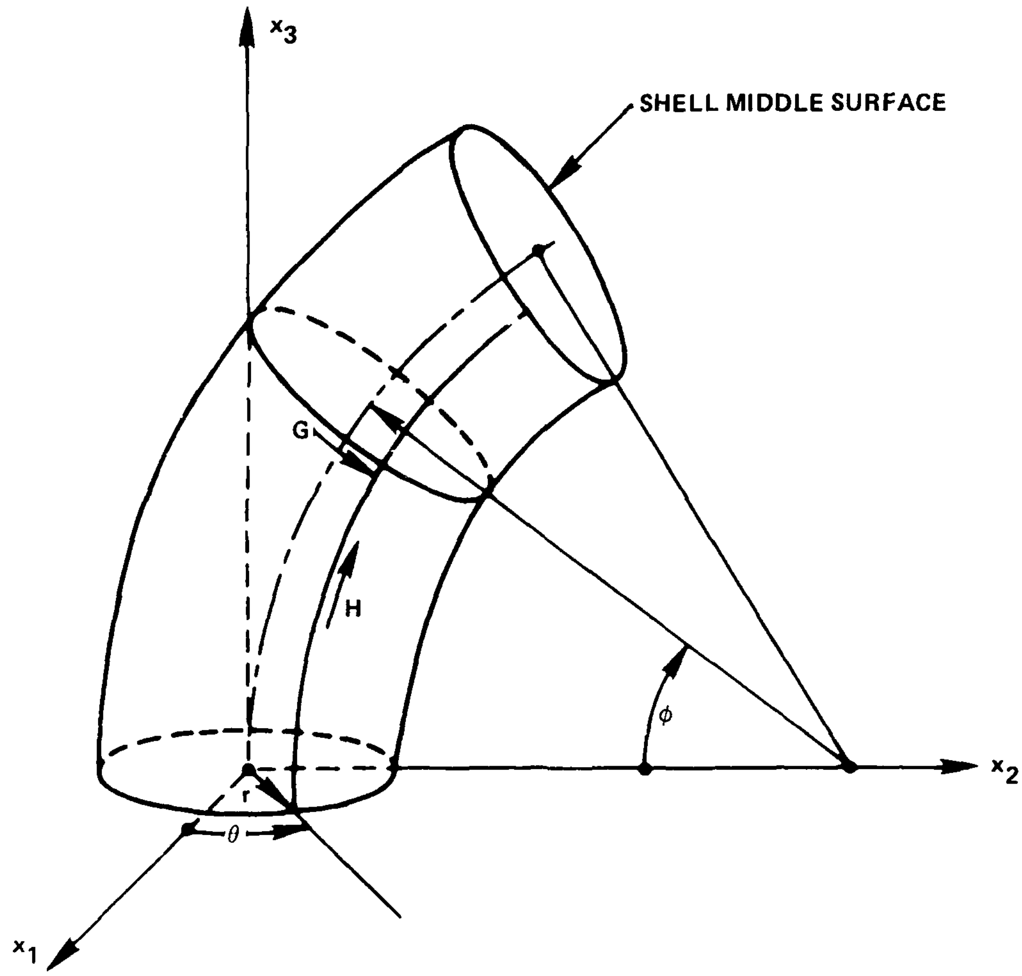

Figure 10.4 - TORUS

10.3.4.8 MAPPING DIRECTIVE 'ZOFXY'

THIS DIRECTIVE MAPS COORDINATES TO A SURFACE WHICH IS DEFINED AS SOME FUNCTION OF THE 'Z' COORDINATE. SEE FIGURE 10.5.

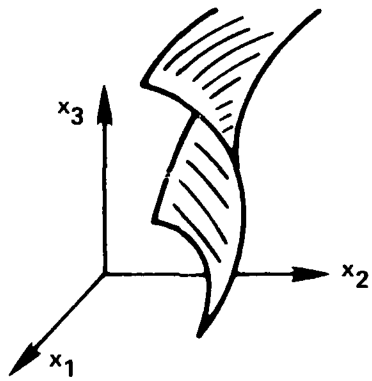

Figure 10.5 - ZOFXY

THIS MAPPING IS A SURFACE MEASURING MAPPING.

NOTES	DATA TYPE	VARIABLE	
	CARD 1.1		
(1)	A	WORD	'ZOFXY'

(2) CARD 1.2

I	NODE	GRIDPOINT NUMBER
R	X	X COORDINATE OF THE NODE
R	Y	Y COORDINATE OF THE NODE
R	Z	Z COORDINATE OF THE NODE
R	DERIVATIVE	DZ/DX AT THE NODE
R	DERIVATIVE	DZ/DY AT THE NODE

NOTES:

1. BEGIN THE ENTRY OF THIS DIRECTIVE IN COLUMN 1.

2. CARDS 1.2 ARE TO BE REPEATED UNTIL THE ENTIRE SET OF COORDINATES TO BE MAPPED IS OBTAINED. NOTE THAT EACH ENTRY ON A CARD BECOMES THE DEFAULT VALUE FOR SUBSEQUENT CARDS UNTIL RESET. THUS, YOU MAY ENTER SIX VALUES ON THE FIRST CARD OF A SET, AND FEWER ON FOLLOWING CARDS UNTIL THESE OTHER VALUES NEED TO BE RESET. BECAUSE OF THE GENERALITY OF THIS SURFACE, HOWEVER, USE OF THIS FEATURE IS NOT EXPECTED.

10.4 EXECUTION

10.4.1 FROM TTY

OBTAIN THE INPUT FILE <A> IN SOME MANNER. THE MOST COMMON WOULD PROBABLY BE TO CREATE THE FILE WITH ONE OF THE SYSTEM EDITORS. THEN,

```
ATTACH,SHELLX,ID=CSRO.
SHELLX.
```

FILE <B> MAY BE MERGED WITH THE BULK INPUT FILE (AGAIN USING ONE OF THE SYSTEM EDITORS) OR OTHERWISE DISPOSED. THE <OUTPUT> FILE MAY BE PRINTED OR EXAMINED AT THE TERMINAL.

10.4.2 BATCH

BATCH JOBS DO NOT PERMIT YOU TO INTERVENE IN THE JOB PROCESS; THUS, ALL FILES TO BE SAVED MUST BE CATALOGED SOMEWHERE. BELOW IS A SAMPLE JOB TO READ THE INPUT FROM THE SYSTEM <INPUT> FILE AND STORE THE MAPPED COORDINATES IN A PERMANENT FILE FOR LATER USE.

```
JOB,CM30000.
CHARGE,YOUR,GOBBLYGOOK.
REQUEST,B,*PF.
ATTACH,SHELLX,ID=CSRO.
SHELLX,INPUT.
CATALOG,B,BFORLATERUSE,ID=YOUR.
*END-OF-RECORD (7/8/9)

    ... SHELLX DATA ...

*END-OF-FILE (6/7/8/9)
```

10.4.3 DEFAULT EXECUTION

THE DEFAULT EXECUTE CARD IS:

```
SHELLX,A,B,OUTPUT.
```

10.5 LIMITATIONS AND REMARKS

1. MINIMUM FIELD LENGTH TO EXECUTE PROGRAM: APPROXIMATELY 30000 WORDS

2. MACHINE: CDC 6000.

3. TIME ESTIMATE: LESS THAN 1/2 SECOND PER NODE.

4. PROGRAM MAINTENANCE: 'SHELLX' IS WRITTEN IN RATIONAL FORTRAN AND IS MAINTAINED BY THE AUTHOR. THE SOURCE CODE IS LOCATED IN THE UPDATE LIBRARY SHELLXPL ,ID=CSRO. THE RELOCATABLE LIBRARY IS LOCATED IN THE EDITLIB LIBRARY SHELLXLIB ,ID=CSRO. THE UPDATE LIBRARY, THE EDITLIB LIBRARY, AND THE ABSOLUTE EXECUTABLE CODE IS ALSO MAINTAINED ON PRIVATE DISK DV4717 AT THE CDC 6400.

5. EXTENSIONS: IT IS RECOMMENDED THAT ANY FUTURE MAPPING TYPES BE OF THE SURFACE MEASURING TYPE TO AVOID THE PROCESS OF CONVERTING COVARIANT STRAIN COMPONENTS TO PHYSICAL STRAIN COMPONENTS. SEE {FUNG}.

10.6 REFERENCES

1. {FUNG} FUNG, Y. C., 'FOUNDATIONS OF SOLID MECHANICS', PRENTICE-HALL, INC., ENGLEWOOD CLIFFS, N.J., 1965, PP 89-92 AND PP 111-115.

CHAPTER 11

'STON'

SUBSTRC TO NASTRAN

DATA FORMAT CONVERTER

11.1 INTRODUCTION

THE AIM OF 'STON' IS TO TRANSLATE A FILE FROM 'SUBSTRUC' INTERMEDIATE FILE <NEWIN> FORMAT TO THE 'NASTRAN' BULK DATA DECK FORMAT. THUS, MANY OF THE SOFTWARE TOOLS DEVELOPED FOR USE WITH NASTRAN MAY BE USED WITH SUBSTRC.

11.2 PROGRAM TECHNIQUE

'STON' READS THE 'SUBSTRC' INTERMEDIATE FILE <NEWIN>. THE COORDINATES ARE CONVERTED TO NASTRAN GRIDPOINTS AND THE CONNECTIVITY TO NASTRAN MESH DESCRIPTION. THE 'STON' TRANSLATION TABLE IS AS FOLLOWS:

- 2 NODE ELEMENTS ARE CONVERTED TO 'CROD' NASTRAN ELEMENTS
- 3 NODE ELEMENTS ARE CONVERTED TO 'CTRIA2' NASTRAN ELEMENTS
- 4 NODE ELEMENTS ARE CONVERTED 'CQUAD1' NASTRAN ELEMENTS
- 8 NODE BRICK ELEMENTS ARE CONVERTED 'CHEXA1' NASTRAN ELEMENTS
- 20 NODE ELEMENTS ARE CONVERTED 'CIHEX2' NASTRAN ELEMENTS

NASTRAN REQUIRES THAT EACH NODE AND ELEMENT BE UNIQUE. 'STON' MEETS THIS NECESSITY BY RENUMBERING THE NODES AND ELEMENTS. THE DUPLICATE NODES AT SUBSTRUCTURE BOUNDARIES ARE NOT ELIMINATED, HOWEVER.

11.3 USING THE PROGRAM

THE FOLLOWING CONTROL CARDS ARE SUFFICIENT TO EXECUTE 'STON':

```
ATTACH,STON,ID=CSPR.
STON.
```

11.3.1 DEFAULT EXECUTION

```
STON,NEWIN,OUTPUT,DATA.
```

11.3.2 FILES

NEWIN	THE INTERMEDIATE FILE PRODUCED BY THE PROGRAM 'WABS'
OUTPUT	PRINTED OUTPUT FROM 'STON'
DATA	THIS IS THE NASTRAN BULK DATA DECK FILE.

11.4 EXAMPLE

THIS EXAMPLE SHOWS THE PRODUCTION OF THE FILE <NEWIN> BY 'WABS' AND THE FILE <DATA> BY 'STON'.

```
COMMENT.----------------------------------------
COMMENT. PRODUCE FILE <NEWIN>.
COMMENT.----------------------------------------
ATTACH,WABS,ID=CSPR.
ATTACH,DATA,YOURDATA,ID=YOUR.
WABS.
UNLOAD,WABS,DATA.
COMMENT.----------------------------------------
COMMENT. TRANSLATE TO NASTRAN INPUT FILE <DATA>
COMMENT.----------------------------------------
ATTACH,STON,ID=CSPR.
STON.
UNLOAD,STON.
```

AT THIS POINT, THE FILE <DATA> EXISTS IN THE NASTRAN BULK DATA DECK FORM. TO CONTINUE, AND PREPARE THE DATA FOR DISPLAY WITH A DISPLAY PACKAGE, ONE MUST TRANSLATE THIS DATA INTO A FORM COMPATIBLE WITH THE PLOTTING DEVICE. IF, FOR EXAMPLE, THE DISPLAY IS TO BE DONE WITH 'STAGING', THE FOLLOWING CONTROL CARDS WOULD BE EXECUTED IMMEDIATELY FOLLOWING THE ABOVE:

```
ATTACH,PROCFIL,PROCFILPRESTAG,ID=CAMK.
BEGIN,IDEALTK,,DB=DBNAME,ID=YOUR,STR1=STRUCTUREN,
   STR2=AMEUPTO40C,STR3=HARACTERSL,STR4=ONG,
   SUB1=UPTO40CHAR,SUB2=SUBSTRUCTU,SUB3=RENAME.
```

CHAPTER 12

'STRSIFT' - SIFT STRESSES

12.1 INTRODUCTION

'STRSIFT' IS AN INTERFACE BETWEEN THE 'SUBSTRC' PROGRAM ELEMENT TYPES 8 (DOUBLY CURVED SHELL TRIANGLE) AND 13 (OPEN SECTION CURVED BEAM) AND THE UNIVERSITY OF CALGARY PLOTTING PROGRAM 'CONT' (CONT). AS SUCH, IT PROCESSES THE 'SUBSTRC' INTERMEDIATE DATA FILE <NEWIN> AND ONE OF THE SUBSTRC STRESS OUTPUT FILES TO PRODUCE A FILE COMPATIBLE WITH THE BULK OF THE INPUT DATA TO 'CONT'. 'STRSIFT' MAKES 4 ADDITIONAL FILES WHICH MAY BE REUSED FOR FURTHER SIFTING.

'STRSIFT' IS DESIGNED TO FILTER THE 'SUBSTRC' INTERMEDIATE FILE <NEWIN> WITH USER-DEFINED FILTERS. THUS, 'STRSIFT' WILL PUT ON THE OUTPUT FILES <DATA> AND <TAPE11> ONLY THOSE ELEMENTS AND COORDINATES WHICH PASS THRU THE FILTER(S). YOU ALSO HAVE THE OPTION OF UNROLLING AN AXISYMMETRIC SURFACE ABOUT ONE OF 3 AXES.

'STRSIFT' IS DESIGNED TO LOGICALLY AND ACTUALLY SEPARATE EACH SPECIFIC TASK INTO A SINGLE MODULE OR SUBROUTINE. THIS KIND OF CONSTRUCTION MAKES FURTHER CHANGES TO 'STRSIFT' FEASIBLE BY OTHER THAN THE ORIGINAL DESIGNER. IT IS WRITTEN IN THE PROGRAMMING LANGUAGES 'RATFOR' AND 'FORTRAN'.

12.2 FILES

INPUT	USER INPUT. SECTION 3 OF THIS REPORT GIVES DETAILED EXPLANATIONS OF USER INPUT.
OUTPUT	PRINTED OUTPUT - USUALLY ABOUT A PAGE OR TWO. THE MAXIMUM, MINIMUM AND DIFFERENCES OF THE COORDINATES AND THE STRESSES ARE PRINTED HERE, WHICH ALLOWS YOU TO GET AN IDEA OF WHAT THE INPUT TO 'CONT' SHOULD BE.
NEWIN	THE INTERMEDIATE 'SUBSTRC' FILE PRODUCED BY 'WABS'

STRSIFT
FILES

DATA — THE CODED 'STRSIFT' OUTPUT FILE SUITABLE FOR FURTHER PROCESSING, POSSIBLY BY A PLOTTING PROGRAM. IT CONTAINS ONE PARTITION FOR EACH OF THE STRESSES. EACH PARTITION ENDS WITH A FORTRAN WRITTEN 'ENDFILE' MARK. EACH PARTITION CONTAINS N RECORDS, WHERE N IS THE NUMBER OF ELEMENTS PASSED THRU THE USER-DEFINED FILTERS MULTIPLIED BY THE NUMBER OF INTEGRATION POINTS PER ELEMENT. THE FORMAT OF EACH RECORD ON THE DATA FILE IS (3E15.7,I2). EACH RECORD IN EACH PARTITION CONTAINS

X, Y, Z, FLAG

WHERE:

X IS THE REAL X COORDINATE OF THE INTEGRATION POINT,

Y IS THE REAL Y COORDINATE OF THE INTEGRATION POINT,

Z IS THE REAL STRESS VALUE AT THE INTEGRATION POINT.

FLAG IS AN INTEGER WHICH SIGNALS THE END OF THE DATA. FLAG = 0 MEANS MORE DATA FOLLOWS; FLAG = 99 SIGNALS END OF DATA.

TAPE11 — THE CODED 'STRSIFT' OUTPUT FILE OF THE GRIDPOINT COORDINATES OF THE FINITE ELEMENT MESH IN A FORM WHICH IS COMPATIBLE WITH THE 'CONT' PROGRAM. THIS FILE IS SAVABLE. ONE MIGHT WISH TO SAVE THIS FILE BECAUSE PLOTTING THE <DATA> FILE WITH 'CONT' BY ITSELF GIVES NO INDICATION OF THE LOCATION OF THE NODES AND ELEMENTS.

TAPE62 — ONE OF THE OUTPUT FILES OF THE 'SUBSTRC' ANALYSIS PROGRAM. FOR THE SHELL ELEMENTS (8 & 20), 'SUBSTRC' PUTS OUT TWO STRESS TAPES: TAPE62, AND TAPE63. IF TAPE63 IS BEING USED, IT SHOULD BE ATTACHED AS TAPE62.

MSLMN — THE MASS STORAGE ELEMENT FILE MADE BY 'STRSIFT'. IT CONTAINS ALL THE ELEMENTS NUMBERED SEQUENTIALLY. IT HAS NO REFERENCES TO SUBSTRUCTURES AT ALL. THIS FILE IS SAVABLE.

STRSIFT
FILES

MSXYZ	THE MASS STORAGE COORDINATES FILE MADE BY 'STRSIFT'. IT CONTAINS ALL THE COORDINATES NUMBERED SEQUENTIALLY. IT HAS NO REFERENCES TO SUBSTRUCTURES AT ALL. THIS FILE IS SAVABLE.
MSTRES	THE MASS STORAGE STRESS FILE MADE BY 'STRSIFT'. IT CONTAINS ALL THE STRESSES PRODUCED BY 'SUBSTRC' AT ALL THE ELEMENT INTEGRATION POINTS. IT HAS NO REFERENCES TO SUBSTRUCTURES AT ALL. THIS FILE IS SAVABLE.
MSIPXS	THE SCRATCH MASS STORAGE INTEGRATION POINTS COORDINATES FILE MADE BY 'STRSIFT'. SINCE SOME OF THE COORDINATES COMPUTED FOR A PARTICULAR DISPLAY MAY NOT BE CORRECT FOR ANOTHER DISPLAY, IT IS NOT DESIRABLE TO SAVE THIS FILE BETWEEN VARIOUS RUNS OF 'STRSIFT'.

12.2.1 A NOTE ON THE <DATA> FILE

TO MAKE THINGS EASIER TO HANDLE WHEN YOU ARE VIEWING THE STRESSES ON A 'SCOPE, YOU MAY WANT TO USE THE PROCEDURE CRUMBLE TO BREAK THE DATA FILE INTO PIECES (OF COURSE, CRUMBLE MAY BE USED AT ANY TIME).

TO CREATE A FILE WHICH DOES NOT HAVE ANY END-FILE MARKS (THAT IS, THE FILE IS ONE HUGE PARTITION), USE THE COPYS SYSTEM UTILITY (DESCRIBED MORE FULLY IN REFERENCE {CCRM}) AS FOLLOWS:

```
BEGIN,COPYS,,COPYJ,DATA,NEWFIL.
REWIND NEWFIL.
```

NOTE THAT THE INPUT DATA EXPECTED BY 'CONT' IS TO COME FROM TAPE8, TAPE9, OR TAPE10, SO YOU MAY HAVE TO LOCALLY RENAME THE DATA FILE OR THE OUTPUT FILES OF CRUMBLE AT THE SCOPE. YOU CAN DO THIS WITH THE INTERCOM COMMANDS (REFERENCE {INTERCOM}):

```
UNLOAD,OLDLFN<CR>
BATCH,OLDLFN,RENAME,NEWLFN<CR>
```

STRSIFT
FILES

WHERE OLDLFN IS THE OLD LOGICAL FILE NAME, NEWLFN IS THE NEW LOGICAL FILE NAME, AND <CR> MEANS CARRIAGE RETURN.

12.3 USER INPUT

12.3.1 INTRODUCTION

INPUT IS HANDLED WITH DIRECTIVES AND DATA CARDS ASSOCIATED THEREWITH. INPUT DATA ARE FREE FORMAT, SEPARATED BY A COMMA OR BLANK(S). THERE ARE THREE TYPES OF DATA EXPECTED AS INPUT: INTEGER, REAL AND ALPHABETIC. INTEGER INPUT AND REAL INPUT FOLLOW THE USUAL FORTRAN CONVENTIONS, I.E. INTEGER IS ENTERED WITHOUT A DECIMAL POINT, REALS ARE ENTERED WITH A DECIMAL POINT (AND MAY BE IN EXPONENTIAL FORM). ALPHABETICS ARE USED FOR INPUTTING THE DIRECTIVES AND THE RELATIONS USED TO DEFINE THE FILTERS. THE DATA TYPES ARE INDICATED IN THE INPUT DESCRIPTIONS AS 'I' FOR INTEGER, 'R' FOR REAL, AND 'A' FOR ALPHABETIC.

FILTERING IS FIRST PERFORMED ON THE NODAL COORDINATES. ANY NODE WHICH HAS COORDINATES WHICH DO NOT PASS THRU THE USER DEFINED FILTERS ARE ELIMINATED. SECOND, THE ELEMENTS ARE EXAMINED. THOSE ELEMENTS CONTAINING 'ELIMINATED' NODES ARE THEMSELVES ELIMINATED, WITH ALL THE NODES ASSOCIATED WITH THEM. THIS SECOND STEP MAY THEREFORE REMOVE MORE NODES THAN YOU EXPECT!

12.3.2 DIRECTIVES IN 'STRSIFT'

THE FOLLOWING DIRECTIVES ARE AVAILABLE:

MESH	DISPLAY FEM MESH. <TAPE11> IS NOT MADE WITHOUT THIS DIRECTIVE.

STRSIFT
USER INPUT - DIRECTIVES

MY	INVOKE USER PROGRAMMING
PICTURE DEFINITION	DEFINE THE EXTENT OF THE PICTURE TO BE DRAWN.
POLAR FILTER	FILTER ELEMENTS PER ANGLE CRITERIA
RADIAL FILTER	FILTER ELEMENTS PER RADIAL CRITERIA
UNROLL	UNROLL A SURFACE INTO 2D
VIEW AXIS	DEFINE A VIEW DIRECTION
XYZ FILTER	FILTER ELEMENTS PER COORDINATE DATA

12.3.2.1 MESH

MESH PERMITS YOU TO DISPLAY THE FINITE ELEMENT MESH. ONE MIGHT WISH TO SAVE THIS FILE BECAUSE PLOTTING THE <DATA> FILE WITH 'CONT' BY ITSELF GIVES NO INDICATION OF THE LOCATION OF THE NODES AND ELEMENTS. THUS, IF YOU DESIRE TO SAVE THE MESH COORDINATES IN A FORM COMPATIBLE WITH 'CONT', <TAPE11> SHOULD BE CATALOGED AFTER THE 'STRSIFT' RUN.

NOTES	DATA TYPE	VARIABLE
	CARD 1	
(1)	A CARD	'MESH'

NOTES:

1. THE WORD 'MESH' IS ENTERED AS THE FIRST FOUR CHARACTERS ON THE INPUT LINE.

EXAMPLE: PROVIDE FOR DRAWING THE MESH OF THE DISPLAY.

SOLUTION: GIVE THE FOLLOWING DIRECTIVE TO 'STRSIFT':

```
MESH
```

12.3.2.2 PICTURE DEFINITION

PICTURE DEFINITION ALLOWS YOU TO DEFINE THE LIMITS OF YOUR DISPLAY AND HENCE 'ZOOM' IN ON AN AREA OF INTEREST. PICTURE DEFINITION IS A 2 CARD BLOCK.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'PICTURE DEFINITION'
(2)	CARD 2		
(3)	R	XLL	X COORDINATE OF THE LOWER LEFT CORNER OF THE PICTURE
	R	YLL	Y COORDINATE OF THE LOWER LEFT CORNER OF THE PICTURE
	R	XUR	X COORDINATE OF THE UPPER RIGHT CORNER OF THE PICTURE
	R	YUR	Y COORDINATE OF THE UPPER RIGHT CORNER OF THE PICTURE

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!
2. EACH ENTITY ON A CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).
3. IF THE 'UNROLL' DIRECTIVE IS USED SIMULTANEOUSLY WITH 'PICTURE DEFINITION',

STRSIFT
'PICTURE DEFINITION' DIRECTIVE

SPECIFY THE PICTURE DEFINITION IN TERMS OF THE UNROLLED STRUCTURAL DIMENSIONS. THUS, IF A CYLINDER OF DIAMETER 10 IS UNROLLED ABOUT THE Y AXIS, THE RANGE OF X DIMENSIONS TO CONSIDER FOR PICTURE DEFINITION IS FROM 0 TO 31.415.

EXAMPLE: EXCLUDE FROM THE DISPLAY ALL THOSE NODES WHICH LIE OUTSIDE THE UNIT SQUARE.

SOLUTION: PROVIDE A PICTURE DEFINITION TO 'DFLSIFT' AS FOLLOWS:

```
PICTURE DEFINITION
0,0,1,1
```

12.3.2.3 POLAR FILTER

POLAR FILTER PERMITS YOU TO EXCLUDE ELEMENTS FROM A DISPLAY WHICH DO NOT LIE WITHIN A REGION DEFINED BY POLAR ANGLES. POLAR FILTER IS A 3 CARD BLOCK. THERE ARE A MAXIMUM ALLOWABLE NUMBER OF 20 FILTERS.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'POLAR FILTER'
	CARD 2		
(2)	I	NPLRTST	NUMBER OF POLAR FILTER TESTS
(3)	CARD 3.1		
(4)	A	PLRDIR	POLAR ANGLE DIRECTION
(5)	A	PLPREL	RELATIONAL SPECIFICATION
(6)	R	PLPVAL	VALUE TO BE USED IN THE FILTER

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!
2. THE MAXIMUM NUMBER OF FILTERS IS 20.
3. REPEAT CARDS IN THIS SET UNTIL ALL THE REQUIRED FILTERS HAVE BEEN DEFINED. EACH ENTITY ON A

CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).

4. PERMISSIBLE SPECIFICATIONS FOR MEASURING THE ANGULAR DIRECTION ARE 'XTOY', 'YTOZ', AND 'ZTOX'. ALTERNATIVELY, THESE DIRECTIONS MAY BE SPECIFIED BY '1', '2', OR '3', RESPECTIVELY.

5. RELATIONS WHICH ARE TO BE USED IN THE FILTERS ARE LIMITED TO THE FOLLOWING VALID TWO CHARACTER ALPHABETIC ENTRIES:
   - EQ - EQUAL;
   - GE - GREATER THAN OR EQUAL TO;
   - GT - GREATER THAN;
   - LE - LESS THAN OR EQUAL TO;
   - LT - LESS THAN;
   - NE - NOT EQUAL TO.

6. THE FILTER RANGE IS FROM -180 TO +180 DEGREES.

EXAMPLE: ESTABLISH A FILTER WHICH PASSES THOSE ELEMENTS LYING BETWEEN -43 DEGREES AND +43 DEGREES IN THE Y-Z PLANE.

SOLUTION: ESTABLISH A 'STRSIFT' FILTER AS FOLLOWS:

```
POLAR FILTER
2
YTOZ,GE,-43.0
YTOZ,LE,+43.0
```

STRSIFT
'RADIAL FILTER' DIRECTIVE

12.3.2.4 RADIAL FILTER

RADIAL FILTER PERMITS YOU TO EXCLUDE ELEMENTS FROM A DISPLAY WHICH DO NOT LIE WITHIN A CIRCLE. CAUTION: THIS FILTER WORKS IN A COMPLETE CIRCLE! RADIAL FILTER IS A 3 CARD BLOCK. THERE ARE A MAXIMUM ALLOWABLE NUMBER OF 20 FILTERS.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'RADIAL FILTER'
	CARD 2		
(2)	I	NRDLTST	NUMBER OF RADIAL FILTER TESTS
(3)	CARD 3.1		
(4)	I	NXRDL1	NUMBER OF THE FIRST COORDINATE USED TO FORM THE RADIUS
	I	NXRDL2	NUMBER OF THE SECOND COORDINATE USED TO FORM THE RADIUS
(5)	A	RDLREL	RELATIONAL SPECIFICATION
	R	RDLVAL	VALUE TO BE USED IN THE FILTER
(6)	R	RDLCTR1	FIRST COORDINATE OF THE CENTER OF THE RADIUS
	R	RDLCTR2	SECOND COORDINATE OF THE CENTER OF THE RADIUS

STRSIFT
'RADIAL FILTER' DIRECTIVE

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!

2. THE MAXIMUM NUMBER OF FILTERS IS 20.

3. REPEAT CARDS IN THIS SET UNTIL ALL THE REQUIRED FILTERS HAVE BEEN DEFINED. EACH ENTITY ON A CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).

4. THE COORDINATES SPECIFIED HERE MAY BE ANY TWO OF THE ELEVEN. THE MOST USEFUL WILL PROBABLY BE COORDINATES 3, 6 AND 9 (X, Y, AND Z, RESPECTIVELY).

5. RELATIONS WHICH ARE TO BE USED IN THE FILTERS ARE LIMITED TO THE FOLLOWING VALID TWO CHARACTER ALPHABETIC ENTRIES:
   - EQ - EQUAL;
   - GE - GREATER THAN OR EQUAL TO;
   - GT - GREATER THAN;
   - LE - LESS THAN OR EQUAL TO:
   - LT - LESS THAN;
   - NE - NOT EQUAL TO.

6. THE DEFAULT VALUES OF THE CENTER ARE 0,0. DEFINING THE CENTER AT SOME OTHER POINT IN SPACE PERMITS VARIOUS PORTIONS OF THE STRUCTURE TO BE CARVED AWAY.

EXAMPLE: DISPLAY ALL THOSE LIBRARY ELEMENT TYPE 8'S WHICH ARE AT A RADIUS OF 12.5 OR LESS FROM THE Z AXIS.

SOLUTION: ESTABLISH A 'STRSIFT' FILTER AS FOLLOWS:

```
RADIAL FILTER
1
3,6,LE,12.5,0.0,0.0
```

12.3.2.5 UNROLL

UNROLL PERMITS YOU TO DISPLAY A SURFACE IN 2 DIMENSIONS BY UNROLLING IT ABOUT AN AXIS. DEFAULT IS NOT UNROLL, THAT IS, IF THE UNROLL DIRECTIVE IS NOT SELECTED, THE VIEW WILL BE A PROJECTED IMAGE. UNROLL IS A TWO CARD OPTION.

NOTES	DATA TYPE	VARIABLE	
		CARD 1	
(1)	A	CARD	'UNROLL'
(2)	A	CARD	AXIS NAME OR NUMBER
		CARD 2	
(3)	R	X	FIRST COORDINATE OF UNROLLING CENTER
	R	Y	SECOND COORDINATE OF UNROLLING CENTER

NOTES:

1. ENTER THE WORD 'UNROLL' BEGINNING IN COLUMN 1.

2. PERMISSIBLE AXIS NAMES ARE 'X', 'Y', 'Z'. SYNONYMS ARE '1', '2', AND '3', RESPECTIVELY. THE AXIS NAMES ARE SEPARATED FROM THE DIRECTIVE BY A COMMA (,) OR ONE OR MORE BLANKS ( ).

3. THE COORDINATES OF UNROLLING CENTER ARE GIVEN IN THE ORDER X-Y, Y-Z, OR Z-X, DEPENDING ON THE AXIS SPECIFIED ON CARD 1.

EXAMPLE: UNROLL A CYLINDER LOCATED AT THE ORIGIN WITH ITS AXIS COINCIDENT WITH THE Z AXIS.

STRSIFT
'UNROLL' DIRECTIVE

SOLUTION: USE THE FOLLOWING INPUT:

```
UNROLL Z
0.0,0.0
```

12.3.2.6 VIEW AXIS

VIEW AXIS PERMITS YOU TO CHANGE THE AXIS ALONG WHICH THE STRUCTURE IS PROJECTED. THE DEFAULT PROJECTION IS THE Z AXIS. VIEW AXIS IS A 1 CARD BLOCK.

NOTES	DATA TYPE	VARIABLE	
		CARD 1	
(1)	A	CARD	'VIEW AXIS'
(2)	A	CARD	AXIS NAME OR NUMBER

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!

2. PERMISSIBLE AXIS NAMES ARE 'X', 'Y', 'Z'. SYNONYMS ARE '1', '2', AND '3', RESPECTIVELY. THE AXIS NAME IS SEPARATED FROM THE DIRECTIVE BY ONE OR MORE BLANKS ( ).

EXAMPLE: VIEW A PROJECTION BY LOOKING IN THE X DIRECTION.

SOLUTION: INCLUDE IN THE INPUT DATA, THE FOLLOWING CARD:

```
VIEW AXIS X
```

12.3.2.7 XYZ FILTER

XYZ FILTER PERMITS YOU TO EXCLUDE ELEMENTS FROM A DISPLAY WHICH DO NOT LIE WITHIN A REGION SPECIFIED BY COORDINATES OF THE GRIDPOINTS. XYZ FILTER IS A THREE CARD-TYPE SET. CARD 3 MAY BE REPEATED UP TO 20 TIMES, GIVING A MAXIMUM NUMBER OF DEFINABLE FILTERS OF 20.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	CARD	'XYZ FILTER'
	CARD 2		
(2)	I	NXTESTS	NUMBER OF XYZ FILTER TESTS
(3)	CARD 3.1		
(4)	I	FLTRCRD	NUMBER OF THE COORDINATE TO BE FILTERED
(5)	A	XTSTREL	RELATIONAL SPECIFICATION
	R	XTEST	VALUE TO BE USED IN THE FILTER

NOTES:

1. START IN COLUMN 1. IT IS IMPORTANT TO INCLUDE ONE AND ONLY ONE BLANK BETWEEN THE WORDS!
2. THE MAXIMUM NUMBER OF FILTERS IS 20.
3. REPEAT CARDS IN THIS SET UNTIL ALL THE REQUIRED

FILTERS HAVE BEEN DEFINED. EACH ENTITY ON A CARD IS SEPARATED FROM THE OTHERS BY EITHER A COMMA (,) OR A BLANK ( ).

4. ANY OF THE COORDINATES MAY BE SPECIFIED IN A FILTER.

5. RELATIONS WHICH ARE TO BE USED IN THE FILTERS ARE LIMITED TO THE FOLLOWING VALID TWO CHARACTER ALPHABETIC ENTRIES:

   EQ - EQUAL;
   GE - GREATER THAN OR EQUAL TO;
   GT - GREATER THAN:
   LE - LESS THAN OR EQUAL TO;
   LT - LESS THAN;
   NE - NOT EQUAL TO.

EXAMPLE: PLOT ONLY THOSE COORDINATES (AND HENCE ELEMENTS) OF LIBRARY ELEMENT TYPE 8 WHICH LIE BETWEEN X COORDINATE 3.0 AND 15.0.

SOLUTION: ESTABLISH A 'STRSIFT' FILTER AS FOLLOWS:

```
XYZ FILTER
2
3,GE,3.0
3,LE,15.0
```

12.4 MY

'MY' PERMITS AN ADVANCED USER TO PUT HIS OWN CODING INTO 'STRSIFT' WITHOUT RADICALLY ALTERING THE PROGRAM STRUCTURE. YOU MUST PROVIDE A ROUTINE NAMED 'MY' WHICH WILL HANDLE ANY OF YOUR INPUT ON THE FIRST CALL, AND WHICH DOES THE FILTERING ON A SECOND CALL. 'MY' IS INITIALLY A 1 CARD BLOCK; YOU MAY OF COURSE DO INPUT/OUTPUT IN YOUR OWN CODE. YOU MAY ADD ANY OTHER ROUTINES DESIRED AS WELL.

THE COMMON BLOCK /MINE/ IS PROVIDED FOR USERS. IT CONTAINS 100 WORDS, THE FIRST OF WHICH IS SET TO INTEGER 1.

EXAMPLE: SET UP A FILTER WHICH PASSES ONLY ODD NUMBERED ELEMENTS.

SOLUTION: PROVIDE THE ROUTINE 'MY' AS FOLLOWS, AND RELOAD AND EXECUTE THE PROGRAM WITH THE 'MY' DIRECTIVE:

```
      SUBROUTINE MY
      COMMON /MINE/ USER(100)
      INTEGER USER
      COMMON /PLOTLMN/ PLOTLMN(2048)
      LOGICAL PLOTLMN
      COMMON /TOTALS/ TOTNODS, TOTLMNS

*     FIRST TIME WE ENTER THE PROGRAM
      IF (USER(2)  .NE. 0 ) GOTO 10
         USER(2) = 1
         RETURN

*     SECOND TIME WE ENTER THE PROGRAM
   10 CONTINUE
      DO 20 I = 2, TOTLMNS, 2
      PLOTLMN(I) =  .FALSE.
   20 CONTINUE
      RETURN
      END
```

12.5 EXECUTION

12.5.1 FROM BATCH...FIRST RUN:

```
JOBCARD,CM70000.
CHARGE,YOUR,GOBBLYGOOK.
COMMENT.----------------------------------------
COMMENT. PRODUCE FILE <NEWIN>.
COMMENT.----------------------------------------
ATTACH,WABS,ID=CSPR.
ATTACH,DATA,YOURDATA,ID=YOUR.
WABS.
UNLOAD,WABS,DATA.
COMMENT.----------------------------------------
COMMENT. ATTACH TAPE62, RESERVE PERM FILE
COMMENT. SPACE FOR OTHER FILES.
COMMENT.----------------------------------------
ATTACH,TAPE62,YOURTAPE62FROMSUBSTRC,ID=YOUR.
REQUEST,MSLMN,*PF.
REQUEST,MSXYZ,*PF.
REQUEST,MSTRES,*PF.
REQUEST,DATA,*PF.
REQUEST,TAPE11,*PF.
COMMENT.----------------------------------------
COMMENT. EXECUTE 'STRSIFT', SAVE FILES
COMMENT.----------------------------------------
ATTACH,STRSIFT,ID=CSPR.
STRSIFT,,,NEWIN.
CATALOG,MSLMN,YOURMSLMNANALYSISNAME,ID=YOUR.
CATALOG,MSXYZ,YOURMSXYZANALYSISNAME,ID=YOUR.
CATALOG,MSTRES,YOURMSTRESANALYSISNAME,ID=YOUR.
CATALOG,DATA,YOURANALYSISNAMEPLOTDATA,ID=YOUR.
CATALOG,TAPE11,YOURANALYSISNAMETAPE11,ID=YOUR.
```

12.5.2 FROM BATCH...SUBSEQUENT RUNS:

```
JOBCARD,CM70000.
CHARGE,YOUR,GOBBLYGOOK.
COMMENT.----------------------------------------
COMMENT. ATTACH PERM FILES, REQUEST SPACE FOR
```

STRSIFT
EXECUTION

```
COMMENT. <DATA> AND <TAPE11>
COMMENT.----------------------------------------
ATTACH,MSLMN,YOURMSLMNANALYSISNAME,ID=YOUR.
ATTACH,MSXYZ,YOURMSXYZANALYSISNAME,ID=YOUR.
ATTACH,MSTRES,YOURMSTRESANALYSISNAME,ID=YOUR.
REQUEST,DATA,*PF.
REQUEST,TAPE11,*PF.
COMMENT.----------------------------------------
COMMENT. EXECUTE 'STRSIFT', SAVE FILES
COMMENT.----------------------------------------
ATTACH,STRSIFT,ID=CSPR.
STRSIFT,,,NEWIN.
CATALOG,DATA,YOURANALYSISNAMEPLOTDATA,ID=YOUR.
CATALOG,TAPE11,YOURANALYSISNAMETAPE11,ID=YOUR.
```

12.5.3 FROM TTY

NOT POSSIBLE BECAUSE 'STRSIFT' TAKES TOO MUCH CM.

12.5.4 DEFAULT EXECUTE CARD

```
STRSIFT,INPUT,OUTPUT,INFILE,DATA,DUMMY,TAPE62,DUMMY,
   MSLMN,MSXYZ,MSTRES.
```

12.6 LIMITATIONS AND REMARKS

1. LARGEST NUMERICAL MODEL: 2048 ELEMENTS AND 2048 NODES.

2. ELEMENT TYPES HANDLED: 8 (DOUBLY CURVED SHELL TRIANGLE) AND 13 (OPEN SECTION CURVED BEAM).

3. MACHINE: CDC 6000 SERIES.

4. CENTRAL MEMORY: 70000 WORDS.

5. TIME ESTIMATE: ABOUT 5 NODES PER CPU SECOND.

6. PROGRAM MAINTENANCE: THE PROGRAM IS CURRENTLY BEING MAINTAINED BY THE AUTHOR. SOURCE CODE IS LOCATED IN THE UPDATE PROGRAM LIBRARY CSROSTRSIFTPL, ID=CSRO. COMPILED ROUTINES ARE IN THE PRELOAD LIBRARY CSROSTRSIFTPRE, ID=CSPO. ABSOLUTE (TASK LOADED) FILE IS STRSIFT,ID=CSPR. COPIES OF THE FILES ARE MAINTAINED ON DISK DV4717.

7. PLACES FOR IMPROVEMENT: 'STRSIFT' COULD BE EXTENDED TO HANDLE ALL THE ELEMENT TYPES IN THE 'SUBSTRC' LIBRARY.

12.7 CRUMBLE

'CRUMBLE' IS A CYBER CONTROL LANGUAGE (REFERENCE (CCL)) PROCEDURE WHICH BREAKS UP A FILE (SAY, <DATA>) CREATED WITH FORTRAN. EACH OF THE PARTITIONS IN <DATA> BECOMES A SEPARATE FILE. EACH OF THE PARTITIONS IS WRITTEN TO PERMANENT FILE DISC, AND MAY BE CATALOGED AT THE OPTION OF THE USER. NONE OF THE FILES ARE REWOUND.

EXECUTION:

```
ATTACH,PROCFIL,CCLLIB,ID=CSRO.
BEGIN,CRUMBLE,PROCFIL,URTAPE,NAME,N.
```

STRSIFT
CRUMBLE

BEGIN	INITIATES EXECUTION OF THE PROCEDURE
CRUMBLE	IS THE NAME OF THE PROCEDURE
PROCFIL	IS THE NAME OF THE PROCEDURE FILE WHENCE THIS PROCEDURE IS BEING EXECUTED.
URTAPE	IS YOUR TAPE (PRODUCED BY A FORTRAN PROGRAM). DEFAULT VALUE: URTAPE = DATA
NAME	IS THE NAME OF THE FILE(S) TO BE PRODUCED BY CRUMBLE, DEFAULT VALUE: NAME = FILE
N	IS THE NUMBER OF FILES EXPECTED ON URTAPE. DEFAULT VALUE: N = 7

EXAMPLE: BREAK UP THE FILE <DATA> AND SAVE THE 4TH PARTITION ON PERMANENT FILE.

SOLUTION: AT A TERMINAL, EXECUTE THE FOLLOWING COMMANDS:

```
ATTACH,PROCFIL,CCLLIB,ID=CSRO.
ATTACH,DATA,YOURDATAFILE,ID=YOUR.
BEGIN,CRUMBLE.
CATALOG,FILE4,FILE4,ID=YOUR.
```

NOTES:

1. YOU NOW HAVE THE FOLLOWING FILES ATTACHED TO YOUR TERMINAL: <PROCFIL>, <DATA>, <FILF1>, <FILE2>, <FILE3>, <FILE4>, <FILE5>, <FILE6>, <FILE7>.

2. NONE OF THE FILES ARE REWOUND.

3. EACH OF THE FILES <FILEN> IS WRITTEN TO PERMANENT FILE, SO YOU CAN SAVE ANY OF THEM BY EXECUTING A PROPER CATALOG.

12.8 FILE STRUCTURE

THE KNOWLEDGE OF THE FILE STRUCTURE USED BY 'STRSIFT' IS NOT NECESSARY FOR ITS USE. HOWEVER, THIS KNOWLEDGE WOULD BE INVALUABLE TO SOMEONE WHO WISHES TO MODIFY THE PROGRAM. HENCE, THIS SECTION DESCRIBES THE MASS STORAGE RANDOM ACCESS FILES USED BY 'STRSIFT'.

12.8.1 MSLMN

MSLMN IS THE MASS STORAGE ELEMENT FILE.

12.8.1.1 MAIN INDEX

THE MAIN INDEX IS NAMED LMASTER DIMENSIONED 10 WORDS

WORD ADDRESS TO:
1 LLISTYP(2048) - A LIST OF THE ELEMENT TYPES
2 LMNNDX(2048) - THE FILE SUBINDEX
3 TOTNODS(2) - THE TOTAL NUMBER OF NODES AND ELEMENTS

12.8.1.2 SUBINDEX

LMNNDX IS SET AS THE FILE SUBINDEX WITH A CALL TO STINDX. EACH ENTRY IS A POINTER TO THE MESH FOR THAT ELEMENT; I.E. LMNNDX(36) POINTS TO THE NODE NUMBERS COMPRISING THE 36TH ELEMENT (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

STRSIFT
FILE STRUCTURE

12.8.2 MSXYZ

MSXYZ IS THE MASS STORAGE COORDINATES FILE.

12.8.2.1 MAIN INDEX

THE MAIN INDEX IS NAMED XMASTER DIMENSIONED 5 WORDS

WORD ADDRESS TO:
1 TOTNODS(2) - THE TOTAL NUMBER OF NODES AND ELEMENTS
2 XLISTYP(TOTNODS) - A LIST OF THE TYPE OF ELEMENT TO WHICH THIS GRIDPOINT BELONGS
3 XYZXTM(18,2) - A LIST OF THE EXTREME VALUES OF COORDINATES FOR THIS ANALYSIS. NOTE THAT AN ANALYSIS WHICH USES SEVERAL KINDS OF ELEMENTS WILL PROBABLY HAVE MIXED UP EXTREME VALUES.
4 XYZNDX(2048) - THE SUBINDEX TO THE FILE

12.8.2.2 SUBINDEX

XYZNDX IS SET AS THE FILE SUBINDEX WITH A CALL TO STINDX. EACH ENTRY IS A POINTER TO THE COMPLETE SET OF COORDINATES FOR THE GRIDPOINT; E.G., XYZNDX(273) POINTS TO ALL THE COORDINATES ASSOCIATED WITH THE 273RD NODE (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

12.8.3 MSTRES

MSTRES IS THE MASS STORAGE STRESS FILE.

STRSIFT
FILE STRUCTURE

12.8.3.1 MAIN INDEX

THE MAIN INDEX TO THE FILE IS NAMED SMASTER DIMENSIONED 4 WORDS.

WORD ADDRESS TO:
  1 SPLOTS(13) - THE ARRAY WHICH TELLS WHICH (IF ANY) PLOTS ARE TO BE MADE.
    IF SPLOTS(I) = 1, PLOT THIS STRESS,
    IF SPLOTS(I) = 0, DO NOT PLOT THIS STRESS.
  2 STRSNDX(2048) - THE FILE SUBINDEX
  3 STRSXTM(13,2) - THE EXTREME STRESS VALUES.

12.8.3.2 SUBINDEX

STRSNDX IS SET BY A CALL TO STINDX. EACH ELEMENT OF STRSNDX IS A POINTER TO THE SET OF STRESSES FOR AN ELEMENT FOR ALL INTEGRATION POINTS. THUS, FOR LIBRARY ELEMENT TYPE 8 FOR EXAMPLE, STRSNDX(456) POINTS TO A 7 * 7 ARRAY OF STRESSES (7 INTEGRATION POINTS) * (THE STRESSES GG, HH, GH, MAXIMUM PRINCIPAL STRESS, MINIMUM PRINCIPAL STRESS, MAXIMUM SHEAR STRESS, AND THE HENCKY-VON MISES STRESS) FOR THE 456TH ELEMENT (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

12.8.4 MSIPXS

MSIPXS IS THE MASS STORAGE INTEGRATION POINTS COORDINATES FILE.

12.8.4.1 MAIN INDEX

THE MAIN INDEX OF THE FILE IS NAMED IMASTER DIMENSIONED 10 WORDS.

WORD ADDRESS TO:
  1 IPXSNDX(2048) - THE SUBINDEX TO THE FILE

```
2 PLOTLMN(2048) - INDICATES ELEMENTS TO BE PLOTTED
  PLOTLMN(I) = 1 MEANS PLOT ELEMENT I;
  PLOTLMN(I) = 0 MEANS DO NOT PLOT ELEMENT 'I'
3 PLOTXYZ(2048) - INDICATES NODES TO BE PLOTTED
  PLOTXYZ(I) = 1 MEANS PLOT NODE I;
  PLOTXYZ(I) = 0 MEANS DO NOT PLOT NODE 'I'
```

12.8.4.2 SUBINDEX.

IPXSNDX IS SET BY A CALL TO STINDX. EACH ENTRY POINTS TO THE COMPLETE INTEGRATION POINT COORDINATE ARRAY FOR AN ELEMENT. THUS, FOR LIBRARY ELEMENT TYPE 8 FOR EXAMPLE, IPXSNDX(324) POINTS TO A 2 * 7 ARRAY XINT (2 COORDINATES TO BE USED IN THE PICTURE) * (7 INTEGRATION POINTS PER ELEMENT) FOR THE 324TH ELEMENT (SEQUENTIALLY) IN THE ENTIRE STRUCTURAL MODEL.

CHAPTER 13

'WABS'

THE INPUT PREPROCESSOR FOR 'SUBSTRC'

13.1 INTRODUCTION

INPUT TO THE PROGRAM CONSISTS OF ALPHABETIC, INTEGER, AND REAL VARIABLES ON CARDS OR CARD IMAGES. FOR BREVITY, THE WORD 'CARD' WILL HEREAFTER BE UNDERSTOOD TO REFER TO EITHER A CARD OR A CARD IMAGE.

THE PROGRAM USES FREE-FORMAT INPUT, AND ELIMINATES MUCH OF THE (MIS)COUNTING WHICH IS USUALLY A LARGE PART OF FINITE ELEMENT INPUT DATA PREPARATION. VARIABLES ON A CARD ARE SEPARATED BY A COMMA OR BY ONE OR MORE BLANKS. DATA ITEMS MAY BEGIN IN ANY COLUMN ON A CARD. MAXIMUM NUMBER OF COLUMNS PERMITTED IS 80.

DATA ARE ORGANIZED INTO BLOCKS THRU THE USE OF 'DIRECTIVES' AND 'END' CARDS. THE BLOCKS ARE SOMETIMES FURTHER SUBDIVIDED INTO CARDSETS. CARDSETS ARE INDICATED IN THIS MANUAL BY THE STATEMENT: 'CARD M.N', WHERE 'M' IS THE NUMBER OF THE CARDSET, AND 'N' IS THE CARD IN THAT CARDSET.

THE INPUT DATA MUST BE IN THE FOLLOWING ORDER:

1. THE TITLE BLOCK, IF IT EXISTS.

2. THE LIBRARY BLOCK. IF NO TITLE BLOCK EXISTS, THE LIBRARY BLOCK MUST BE THE FIRST BLOCK.

3. ANY OTHER BLOCK. THE INTERSUBSTRUCTURE CONNECTIVITY BLOCK MUST, HOWEVER, BE INPUT AFTER ALL THE SUBSTRUCTURES HAVE BEEN INPUT.

THREE TYPES OF DATA ARE READ BY THE PROGRAM: ALPHABETIC, INTEGER, AND REAL.

ALPHABETIC DATA ARE USED FOR LABELS AND DIRECTIVES. DIRECTIVE NAMES ARE SHOWN IN THIS MANUAL ENCLOSED IN DOUBLE QUOTES ("). ALPHABETIC DATA ARE INDICATED BY AN 'A' IN THE 'DATA TYPE' COLUMN OF THE INPUT VARIABLE SPECIFICATION.

INTEGER DATA ARE USED FOR BOOKKEEPING. INTEGER DATA VARIABLES ARE INDICATED BY AN 'I' IN THE 'DATA TYPE' COLUMN OF THE INPUT VARIABLE SPECIFICATION. INTEGER DATA MUST NOT CONTAIN A DECIMAL POINT.

'WABS' INPUT
INTRODUCTION

REAL DATA ARE USED FOR COORDINATES, MATERIAL PROPERTIES, ETC. REAL DATA VARIABLES ARE INDICATED BY AN 'R' IN THE 'DATA TYPE' COLUMN OF THE INPUT VARIABLE SPECIFICATION. REAL VARIABLES MAY CONTAIN A DECIMAL POINT.

13.1.1 FORMAT OF THE INPUT SPECIFICATIONS

EACH DATA BLOCK IS INTRODUCED BY A BRIEF DISCUSSION OF THE INPUT POSSIBLE IN THE BLOCK. THIS IS FOLLOWED BY THE SPECIFICATIONS FOR EACH VARIABLE ON EACH CARD. THE SPECIFICATIONS ARE IN TURN FOLLOWED BY NOTES WHICH FURTHER EXPLAIN THE INPUT.

THE INPUT SPECIFICATIONS THEMSELVES ARE ORGANIZED INTO FOUR COLUMNS:

THE FIRST COLUMN CONTAINS THE NOTE NUMBER TO WHICH YOU ARE REFERRED FOR FURTHER INFORMATION CONCERNING THIS INPUT CARDSET, CARD, OR VARIABLE.

THE SECOND COLUMN CONTAINS THE DATA TYPE INDICATOR: 'A' FOR ALPHABETIC, 'I' FOR INTEGER, AND 'R' FOR REAL.

THE THIRD COLUMN IS THE VARIABLE NAME; NAMES WHICH END WITH 'DRC' ARE DIRECTIVES.

THE FOURTH COLUMN IS A BRIEF DESCRIPTION OF THE VARIABLE.

'WABS' INPUT
TITLE

13.2 TITLE

THIS BLOCK PERMITS THE TITLING OF OUTPUT. DEFAULT IS 'NO TITLE'.

CARDS ARE READ FROM THE INPUT FILE UNTIL A MAIN DIRECTIVE IS ENCOUNTERED. THESE CARDS ARE ALL LISTED ON THE FIRST PAGE OF THE OUTPUT FOLLOWING THE SUBSTRC BANNER PAGE (ONLY THE FIRST TITLE CARD WILL BE PRINTED ON THE HEADING OF EACH SUBSTRC OUTPUT PAGE). THUS, AS THE FIRST WORD OF YOUR TITLE YOU SHOULD AVOID USING WORDS WHICH BEGIN WITH THE FIRST 4 CHARACTERS OF ANY OF THE MAIN DIRECTIVES. THE TITLE CARD(S) MUST BE THE FIRST CARD(S) IN THE DATA STREAM.

THE TITLE DATA ARE OPTIONAL. UP TO 80 COLUMNS OF TITLE MAY BE ENTERED ON EACH TITLE CARD. UP TO 60 TITLE CARDS MAY BE INPUT.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
	A	CARD	TITLE

13.3 LIBRARY

THE LIBRARY BLOCK SPECIFIES ITEMS TO BE CHOSEN FROM THE PROGRAM LIBRARY TO BE USED IN THE ANALYSIS. THIS BLOCK MUST FOLLOW THE 'TITLE' BLOCK, IF THE 'TITLE' BLOCK EXISTS.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1		
	A	MAINDRC	"LIBRARY"
	CARD 2.1		
	A	LIBRDRC	"ELEMENTS"
	CARD 2.2		
(2)	I	LMNTYPE1	ELEMENT TYPE
	I	LMNTYPE2	ELEMENT TYPE
	I	LMNTYPE3	ELEMENT TYPE
(3)	CARD 3		
	A	LIBRDRC	"DEBUG"
	I	DEBUG	DEBUG SWITCH SETTING

(4) CARD 4.1

A LIBRDRC "TYING TYPES"

CARD 4.2

(5) I TIETYPE NUMBER OF THE TYING TYPE

I NRETAIN NUMBER OF RETAINED NODES

NOTES:

1. ALL OF THE DIRECTIVES WHICH APPEAR IN THIS BLOCK MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS.

2. THE 'LMNTYPE' VARIABLES SELECT ELEMENTS FROM THE ELEMENT LIBRARY. A MAXIMUM OF 3 TYPES MAY BE SELECTED. NOTE: THIS BLOCK IS A MANDATORY BLOCK!

3. USE THIS UNDER DIRECTION OF PROGRAM AUTHOR.

4. THIS BLOCK IS MANDATORY IF THERE ARE TO BE 'TIES' IN ANY SUBSTRUCTURE.

5. THE NUMBER OF RETAINED NODES DEPENDS ON THE TYING TYPE; SEE THE DISCUSSION ON TYING TYPES.

13.4 SUBSTRUCTURE MODELING

THESE DATA DEFINE THE MODEL TO SUBSTRC. SOME OF THE BLOCKS ARE REQUIRED, OTHERS ARE OPTIONAL, DEPENDING ON THE ANALYSIS. ALL OF THE SUBSTRUCTURE MODELING BLOCKS MUST PRECEDE THE INTERSUBSTRUCTURE CONNECTIVITY BLOCK.

THE FOLLOWING IS A LIST OF THE AVAILABLE DIRECTIVES IN THE SUBSTRUCTURE MODELING BLOCK.

BOUNDARY CONDITIONS	OPTIONAL
CONNECTIVITY	REQUIRED
COORDINATES	REQUIRED
DISTRIBUTED LOADS	OPTIONAL
EDGE NODES	REQUIRED
GEOMETRY	OPTIONAL
CONCENTRATED LOADS	OPTIONAL
PROPERTY	REQUIRED
TRANSFORMATIONS	OPTIONAL
TIES	OPTIONAL
WORK HARDENING	OPTIONAL
END	OPTIONAL

THE FOLLOWING DIRECTIVES ARE ALWAYS REQUIRED:

BOUNDARY CONDITIONS
CONNECTIVITY
COORDINATES
EDGE NODES
PROPERTY

NOTE THAT THE BOUNDARY CONDITIONS OPTION MUST BE SPECIFIED IN AT LEAST ONE SUBSTRUCTURE TO REMOVE THE POSSIBILITY OF RIGID BODY MOTION; IT IS NOT A REQUIRED OPTION IN ALL OF THE SUBSTRUCTURES.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	MAINDRC	"SUBSTRUCTURE"
(2)	I	NSBS	NUMBER OF THE SUBSTRUCTURE

NOTES:

1. THIS DIRECTIVE MAY NOT BE ABBREVIATED.
2. SUBSTRUCTURES MAY BE INPUT IN ANY ORDER DESIRED. A CONSISTENT PLAN SHOULD BE FOLLOWED, HOWEVER, WHICH WILL ALLOW YOU TO EASILY INTERPRET BOTH PROGRAM INPUT AND OUTPUT.

13.4.1 BOUNDARY CONDITIONS

THE BOUNDARY CONDITIONS ARE THE CONSTRAINTS WHICH YOU WISH TO APPLY TO THE MODEL. SUBSTRC ALLOWS YOU TO SPECIFY DISPLACEMENTS OTHER THAN ZERO AT THE NODES. THE WORD "DISPLACEMENT" IS HERE TAKEN AS A GENERAL TERM MEANING DEFLECTION, ROTATION, TRANSLATION, ETC, DEPENDING ENTIRELY ON THE DEGREE OF FREEDOM UNDER CONSIDERATION. THESE DATA ARE REQUIRED IN AT LEAST ONE SUBSTRUCTURE IN THE OVERALL MODEL TO PREVENT RIGID BODY MOTION OF THE MODEL.

THIS BLOCK MAY BE SELECTED ONLY ONCE PER SUBSTRUCTURE. OMIT THIS ENTIRE BLOCK IF NO BOUNDARY CONDITIONS ARE TO BE APPLIED TO A SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"BOUNDARY CONDITIONS"
	CARD 2.1		
(2)	R	FASTEN	MAGNITUDE OF THE SPECIFIED DISPLACEMENT
(3)	I	NFIRST	THE NUMBER OF THE FIRST NODE TO BE CONSTRAINED, OR, THE TOTAL NUMBER OF NODES TO BE CONSTRAINED BY THIS DATA BLOCK.
(3)	I	NLAST	THE NUMBER OF THE LAST NODE TO BE CONSTRAINED, OR, 0.
(4)	I	DFIRST	THE NUMBER OF THE FIRST DEGREE OF FREEDOM TO BE CONSTRAINED, OR, THE TOTAL NUMBER OF DEGREES OF FREEDOM TO BE CONSTRAINED.

(4)	I	DLAST	THE NUMBER OF THE LAST DEGREE OF FREEDOM TO BE CONSTRAINED, OR, 0.
(5)	CARD 2.2 -NODE LIST-		
	I	NNODE(1)	FIRST NODE TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1
	I	NNODE(2)	SECOND NODE TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1
		•	
		•	
		•	
(6)	I	NNODE(NFIRST)	LAST NODE TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1
(7)	CARD 2.3 -DEGREE OF FREEDOM LIST-		
	I	IDOF(1)	FIRST D.O.F. TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1
	I	IDOF(2)	SECOND D.O.F. TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1
		•	
		•	
		•	
(8)	I	IDOF(OFIRST)	LAST D.O.F. TO HAVE DISPLACEMENT = 'FASTEN' PER CARD 2.1

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "BOUN"

2. MAGNITUDE OF THE SPECIFIED DISPLACEMENT

3. YOU MAY SPECIFY AN INCLUSIVE RANGE OF NODES TO WHICH THE BOUNDARY CONDITIONS WILL BE APPLIED BE ENTERING 'NFIRST' AND 'NLAST' SUCH THAT 0 < 'NFIRST' < 'NLAST'. FOR EXAMPLE, TO SET DISPLACEMENT OF NODES 2, 3, 4, 5, AND 6 TO THE VALUE OF 'FASTEN' ON CARD 2.1, 'NFIRST' = 2 AND 'NLAST' = 6.
ALTERNATIVELY, YOU MAY SPECIFY THAT THE BOUNDARY CONDITION IS TO APPLY TO A LIST OF NODES. IN THIS CASE, 'NFIRST' = THE LENGTH OF THE LIST, AND 'NLAST' = 0. DO NOT OMIT 'NLAST'! YOU MUST THEN INCLUDE CARD 2.2 TO LIST THESE NODES.

4. YOU MAY SPECIFY AN INCLUSIVE RANGE OF D.O.F.S TO WHICH THE BOUNDARY CONDITIONS WILL BE APPLIED BY ENTERING 'DFIRST' AND 'DLAST' SUCH THAT 0 < 'DFIRST' < 'DLAST'. FOR EXAMPLE, TO SET DISPLACEMENT OF D.O.F.S 2, 3, 4, 5, AND 6 TO THE VALUE OF 'FASTEN' ON CARD 2.1, 'DFIRST' = 2 AND 'DLAST' = 6.
ALTERNATIVELY, YOU MAY SPECIFY THAT THE BOUNDARY CONDITION IS TO APPLY TO A LIST OF D.O.F.S. IN THIS CASE, 'DFIRST' = THE LENGTH OF THE LIST, AND 'DLAST' = 0, OR IS OMITTED. YOU MUST THEN INCLUDE CARD 2.3 TO LIST THESE D.O.F.S.

5. INCLUDE THIS CARD IF, AND ONLY IF, A LIST OF NODES IS TO BE SPECIFIED; 'NLAST' = 0 ON CARD 2.1.

6. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 2.2'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

7. INCLUDE THIS CARD IF, AND ONLY IF, A LIST OF D.O.F.S IS TO BE SPECIFIED; 'DLAST' = 0 ON CARD 2.1.

8. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 2.3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

3.4.2 CONCENTRATED LOADS

CONCENTRATED LOADS ARE LOADS SPECIFIED AT NODES; THESE ARE TYPICALLY FORCES AND MOMENTS. NOTE THAT NODE LOADS FOR AXISYMMETRIC ELEMENTS ARE ACTUALLY LOADS ON A CIRCUMFERENTIAL LINE AND THE VALUE INPUT SHOULD BE THE INTEGRAL OF THE LOAD AROUND THE CIRCUMFERENCE OF THE MODEL.

CONCENTRATED LOADS ARE OPTIONAL INPUT. THIS BLOCK MAY BE SELECTED ONLY ONCE PER SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"CONCENTRATED LOADS"
(2)	CARD 2		
	I	NODE	NUMBER OF THE NODE TO BE LOADED
	R	XLOAD(1)	LOAD IN DIRECTION OF D.O.F. 1
	R	XLOAD(2)	LOAD IN DIRECTION OF D.O.F. 2
		.	
		.	
		.	
(3)	R	XLOAD(NDOF)	LOAD IN DIRECTION OF D.O.F. 'NDOF' FREEDOM AT THE NODE.

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "CONC"

2. IF THE LIST LENGTH IS GREATER THAN 7, CONTINUE THE LISTING ON ADDITIONAL CARD 2'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128. THE CONCENTRATED LOADS FOR ALL DEGREES OF FREEDOM MUST BE GIVEN ON A SINGLE CARD(S) 2. SUBSEQUENT INPUT OF CONCENTRATED LOADS FOR THE SAME NODE WILL OVERWRITE ANY PREVIOUS VALUES ENTERED.

3. THE NUMBER OF DEGREES OF FREEDOM AT A NODE DEPENDS ON THE ELEMENTS SELECTED FORM THE LIBRARY. 'NDOF' IS THE MAXIMUM OF THE NUMBER OF DEGREES OF FREEDOM OF THE ELEMENTS SELECTED. THE FOLLOWING LISTS THE NUMBER OF DEGREES OF FREEDOM FOR EACH ELEMENT TYPE IN THE LIBRARY:

1	AXISYMMETRIC SHELL	3
2	AXISYMMETRIC SOLID TRIANGLE	2
3	PLANE STRESS ISOPARAMETRIC QUAD	2
4	VACANT	0
5	BEAM COLUMN	3
6	PLANE STRAIN TRIANGLE	2
7	LINEAR ISOPARAMETRIC BRICK	3
8	DOUBLY CURVED SHELL TRIANGLE	9
9	3 DIMENSIONAL TRUSS	3
10	AXISYMMETRIC SOLID QUAD	2
11	PLANE STRAIN QUAD	2
12	VACANT	0
13	OPEN SECTION BEAM	8
14	CLOSED SECTION BEAM	6
15	AXISYMMETRIC ISOPARAMETRIC SHELL	4
16	ISOPARAMETRIC BEAM	4
17	VACANT	0
18	MEMBRANE QUAD	3
19	GENERALIZED PLANE STRAIN QUAD	2
20	DOUBLY CURVED SHELL QUAD	9
21	QUADRATIC ISOPARAMETRIC BRICK	3

13.4.3 CONNECTIVITY

THE CONNECTIVITY BLOCK DESCRIBES HOW THE ELEMENTS ARE FORMED BY THE NODES. A MAXIMUM OF 3 ELEMENT TYPES IS PERMITTED PER ANALYSIS. EACH SEPARATE TYPE OF ELEMENT TO BE INPUT REQUIRES A DISTINCT "CONNECTIVITY" BLOCK.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1.1		
(2)	A	SUBSDRC	"CONNECTIVITY"
	CARD 1.2		
(3)	I	LMNTYPE	NUMBER OF THE ELEMENT IN THE LIBRARY
	CARD 1.3		
(4)	I	NUME	ELEMENT NUMBER
	I	NPI(1)	NUMBER OF THE FIRST NODE OF THIS ELEMENT
	I	NPI(2)	NUMBER OF THE SECOND NODE OF THIS ELEMENT
		.	
		.	
		.	
2	I	NPI(NNODE)	THE NUMBER OF THE LAST NODE OF THIS ELEMENT WHERE NNODE IS THE NUMBER OF NODES REQUIRED TO DEFINE THE ELEMENT.

NOTES:

1. A SEPARATE SET OF CONNECTIVITY CARDS IS REQUIRED FOR ELEMENT TYPE IN A SUBSTRUCTURE.

2. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "CONN"

3. THE NUMBER OF THE ELEMENTS IN THE LIBRARY, AND THE NUMBER OF NODES ASSOCIATED WITH EACH NODE OF THE ELEMENTS, ARE LISTED:

1	AXISYMMETRIC SHELL	2
2	AXISYMMETRIC SOLID TRIANGLE	3
3	PLANE STRESS ISOPARAMETRIC QUAD	4
4	VACANT	0
5	BEAM COLUMN	2
6	PLANE STRAIN TRIANGLE	3
7	LINEAR ISOPARAMETRIC BRICK	8
8	DOUBLY CURVED SHELL TRIANGLE	3
9	3 DIMENSIONAL TRUSS	2
10	AXISYMMETRIC SOLID QUAD	4
11	PLANE STRAIN QUAD	4
12	VACANT	0
13	OPEN SECTION BEAM	2
14	CLOSED SECTION BEAM	2
15	AXISYMMETRIC ISOPARAMETRIC SHELL	2
16	ISOPARAMETRIC BEAM	2
17	VACANT	0
18	MEMBRANE QUAD	4
19	GENERALIZED PLANE STRAIN QUAD	4
20	DOUBLY CURVED SHELL QUAD	4
21	QUADRATIC ISOPARAMETRIC BRICK	20

IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

4. THE PROGRAM READS AND THEN STORES THE ELEMENTS IN THE PROPER NUMERICAL SEQUENCE. IT IS THEREFORE POSSIBLE, AND IN SOME CASES, MANDATORY, THAT ELEMENTS BE READ OUT OF NUMERICAL SEQUENCE. BE CAREFUL, HOWEVER, TO ENTER DATA IN A CONSISTENT MANNER TO ALLOW EASY INTERPRETATION LATER.

13.4.4 COORDINATES

COORDINATES DEFINE THE GEOMETRY OF THE ELEMENTS BY GIVING THE LOCATION IN SPACE OF THE NODES. IN SOME CASES, COORDINATES ARE USED TO DEFINE THE SHAPE OF A SURFACE THROUGH THE USE OF DIRECTIONAL DERIVATIVES AT A NODE. IN GENERAL, YOU WILL WISH TO INPUT A SEPARATE COORDINATES BLOCK FOR EACH DISTINCT LIBRARY ELEMENT TYPE IN THE SUBSTRUCTURE BECAUSE EACH TYPE WILL USUALLY HAVE A DIFFERENT NUMBER OF COORDINATES PER NODE.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1.1		
(2)	A	SUBSORC	"COORDINATES"
	CARD 1.2		
	I	LMNTYPE	ELEMENT TYPE TO WHICH THIS NODE BELONGS
(3)	CARD 1.3		
	I	NODE	NUMBER OF THIS NODE
(4)	R	X(1,NODE)	FIRST COORDINATE OF 'NODE'
	R	X(2,NODE)	SECOND COORDINATE OF 'NODE'
		.	
		.	
		.	
(5)	R	X(N,NODE)	LAST COORDINATE OF 'NODE'

NOTES:

1. REPEAT THIS CARD SET UNTIL ALL OF THE COORDINATES FOR A SUBSTRUCTURE HAVE BEEN ENTERED.

2. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "COOR"

3. CARD(S) 1.3 IS REPEATED UNTIL ALL THE COORDINATES FOR ELEMENTS OF TYPE 'LMNTYPE' HAVE BEEN ENTERED.

4. THE NUMBER OF COORDINATES REQUIRED TO BE READ FOR EACH NODE DEPENDS ON THE ELEMENT TYPE AS LISTED:

1	AXISYMMETRIC SHELL	2
2	AXISYMMETRIC SOLID TRIANGLE	2
3	PLANE STRESS ISOPARAMETRIC QUAD	2
4	VACANT	0
5	BEAM COLUMN	2
6	PLANE STRAIN TRIANGLE	2
7	LINEAR ISOPARAMETRIC BRICK	3
8	DOUBLY CURVED SHELL TRIANGLE	11
9	3 DIMENSIONAL TRUSS	3
10	AXISYMMETRIC SOLID QUAD	2
11	PLANE STRAIN QUAD	2
12	VACANT	0
13	OPEN SECTION BEAM	13
14	CLOSED SECTION BEAM	3
15	AXISYMMETRIC ISOPARAMETRIC SHELL	5
16	ISOPARAMETRIC BEAM	5
17	VACANT	0
18	MEMBRANE QUAD	3
19	GENERALIZED PLANE STRAIN QUAD	2
20	DOUBLY CURVED SHELL QUAD	11
21	QUADRATIC ISOPARAMETRIC BRICK	3

THE DEFAULT VALUE OF ANY COORDINATE NOT READ IS 0. NOTE THAT PROGRAMS 'BEAMX' AND 'SHELLX' ARE AVAILABLE AS COORDINATE GENERATORS FOR ELEMENT TYPES 8, 13, AND 20.

5. IF THE LIST LENGTH IS GREATER THAN 7, CONTINUE THE LISTING ON ADDITIONAL CARD 1.3'S

IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

13.4.5 DISTRIBUTED LOADS

DISTRIBUTED LOADS ARE LOADS WHICH EFFECT ENTIRE ELEMENTS, AS OPPOSED TO LOADS WHICH ACT ONLY AT NODES. THESE LOADS ARE TYPICALLY PRESSURE LOADS, BODY FORCE LOADS, GRAVITY LOADS, ETC. FOR THE SIGN CONVENTIONS WHICH RELATE TO LOAD DIRECTION, SEE THE ELEMENT DESCRIPTION.

THE DISTRIBUTED LOADS BLOCK MAY BE SELECTED ONLY ONCE PER SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"DISTRIBUTED LOADS"
(2)	CARD 2.1		
	R	DISTL	VALUE OF THE DISTRIBUTED LOAD
(3)	I	TYPE	TYPE OF DISTRIBUTED LOAD
	CARD 2.2		
(4)	I	LFIRST	FIRST ELEMENT TO BE LOADED, OR, NUMBER OF ELEMENTS TO BE READ FROM CARD 2. 3
(4)	I	LLAST	LAST ELEMENT TO BE LOADED, OR, BLANK.

(5) CARD 2.3 -ELEMENT LIST-

	I	L(1)	FIRST ELEMENT TO BE LOADED
	I	L(2)	SECOND ELEMENT TO BE LOADED
		•	
		•	
		•	
(6)	I	L(LFIRST)	LAST ELEMENT TO BE LOADED

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "DIST"
2. THIS CARD SET IS REPEATED UNTIL ALL THE DISTRIBUTED LOADS FOR A SUBSTRUCTURE HAVE BEEN ENTERED.
3. THE TYPES OF DISTRIBUTED LOADS PERMISSIBLE WITH EACH ELEMENT TYPE ARE DETAILED IN THE ELEMENT DESCRIPTIONS.
4. YOU MAY SPECIFY AN INCLUSIVE RANGE OF ELEMENTS TO WHICH THE DISTRIBUTED LOADS WILL BE APPLIED BY ENTERING 'LFIRST' AND 'LLAST' SUCH THAT 0 < 'LFIRST' < 'LLAST'. FOR EXAMPLE, TO APPLY THE LOAD 'DISTL' TO ELEMENTS 2, 3, 4, 5, AND 6, 'LFIRST' = 2 AND 'LLAST' = 6.
   ALTERNATIVELY, YOU MAY SPECIFY THAT THE DISTRIBUTED LOAD IS TO APPLY TO A LIST OF ELEMENTS. IN THIS CASE, 'LFIRST' = THE LENGTH OF THE LIST, AND 'LLAST' = 0, OR BLANK. YOU MUST THEN INCLUDE CARD 2.3 TO LIST THESE ELEMENTS.
5. OMIT THIS CARD IF ALL THE ELEMENTS LFIRST THROUGH LLAST INCLUSIVE ARE TO BE LOADED.

6. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 2.3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

13.4.6 EDGE NODES

EDGE NODES ARE THOSE NODES WHICH LIE ON THE EDGES OF SUBSTRUCTURES. THESE NODES SERVE TO CONNECT THE SUBSTRUCTURES. IT IS NOT PERMITTED TO PUT 'TIED' NODES INTO THIS LIST OF EDGE NODES; THEY MUST BE 'RETAINED' NODES, OR NODES WHICH ARE NOT INVOLVED WITH TIES. NOTE THAT THE EDGE NODES MAY BE INPUT IN ANY ORDER AS THE PROGRAM AUTOMATICALLY SORTS THEM. WE RECOMMEND THAT YOU PROCEED NEATLY AND CONSISTENTLY, HOWEVER.

THE EDGE NODE BLOCK MAY BE INPUT ONLY ONCE PER SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"EDGE NODES"
(2)	CARD 2		
	I	N1	FIRST EDGE NODE
	I	N2	SECOND EDGE NODE
		.	
		.	
		.	
	I	NLAST	LAST EDGE NODE

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "EDGE"

2. IF THE NUMBER OF EDGE NODES EXCEEDS 16, CONTINUE LISTING ON ADDITIONAL CARD 2'S UNTIL ALL EDGE NODES HAVE BEEN ENTERED. THE MAXIMUM LIST LENGTH IS 128.

13.4.7 GEOMETRY

THE GEOMETRY BLOCK IS REQUIRED INPUT FOR SEVERAL ELEMENTS. THOSE ELEMENTS ARE SO NOTED IN THE ELEMENT DESCRIPTIONS.

THE GEOMETRY BLOCK ALLOWS INPUT FOR SEVERAL MISCELLANEOUS PARAMETERS. THESE INCLUDE: ELEMENT THICKNESS FOR SHELLS, THE BEAM CROSS SECTION NUMBER TO BE EMPLOYED, ETC.

THE GEOMETRY BLOCK MAY BE INPUT ONLY ONCE PER SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"GEOMETRY"
(2)	CARD 2.1		
(3)	R	EGEOM1	GEOMETRY PARAMETER 1
	R	EGEOM2	GEOMETRY PARAMETER 2
	R	EGEOM3	GEOMETRY PARAMETER 3

CARD 2.2

(4)	I	LFIRST	FIRST ELEMENT TO BE DESCRIBED, OR, NUMBER OF ELEMENTS TO BE READ FROM CARD 2. 3
(4)	I	LLAST	LAST ELEMENT TO BE DESCRIBED

(5) CARD 2.3 -ELEMENT LIST-

	I	L(1)	FIRST ELEMENT TO BE DESCRIBED
	I	L(2)	SECOND ELEMENT TO BE DESCRIBED
		.	
		.	
		.	
(6)	I	L(LFIRST)	LAST ELEMENT TO BE DESCRIBED

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "GEOM"
2. REPEAT THIS CARD SET UNTIL ALL THE "GEOMETRY" INPUT FOR A SUBSTRUCTURE HAS BEEN ENTERED.
3. EACH 'EGEOM1', 'EGEOM2', AND 'EGEOM3' DEFAULT TO 0. IF AN ELEMENT REQUIRES ONLY 'EGEOM2', YOU MUST ENTER BOTH 'EGEOM1' AND 'EGEOM2'.
4. YOU MAY SPECIFY AN INCLUSIVE RANGE OF ELEMENTS

TO WHICH THE GEOMETRY WILL BE APPLIED BE ENTERING 'LFIRST' AND 'LLAST' SUCH THAT 0 < 'LFIRST' < 'LLAST'. FOR EXAMPLE, TO SET THE GEOMETRY PARAMETERS FOR ELEMENTS 2, 3, 4, 5, AND 6, 'LFIRST' = 2 AND 'LLAST' = 6. ALTERNATIVELY, YOU MAY SPECIFY THAT THE GEOMETRY IS TO APPLY TO A LIST OF ELEMENTS. IN THIS CASE, 'LFIRST' = THE LENGTH OF THE LIST, AND 'LLAST' = 0, OR BLANK. YOU MUST THEN INCLUDE CARD 2.3 TO LIST THESE ELEMENTS.

5. OMIT THIS CARD IF ALL THE ELEMENTS 'LFIRST' THROUGH 'LLAST' ARE TO BE DESCRIBED.

6. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 2.3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

13.4.8 PROPERTY

THE PROPERTY BLOCK SPECIFIES THE LINEAR ELASTIC MATERIAL PROPERTIES OF ELEMENTS. PROPERTIES MUST BE SPECIFIED FOR ALL ELEMENTS.

THE PROPERTY BLOCK MAY BE ENTERED ONCE PER SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	SUBSDRC	"PROPERTY"
	CARD 2.1		
(2)	R	E	YOUNG'S MODULUS
(3)	R	NU	POISSON'S RATIO
(4)	R	SIGSTAR	YIELD STRENGTH
	CARD 2.2		
(5)	I	LFIRST	FIRST ELEMENT TO BE DESCRIBED, OR, NUMBER OF ELEMENTS TO BE READ FROM CARD 2. 3
(5)	I	LLAST	LAST ELEMENT TO BE DESCRIBED, OR, BLANK.

(6) CARD 2.3 -ELEMENT LIST-

	I	L(1)	FIRST ELEMENT TO BE DESCRIBED
	I	L(2)	SECOND ELEMENT TO BE DESCRIBED
		.	
		.	
		.	
(7)	I	L(LFIRST)	LAST ELEMENT TO BE DESCRIBED

NOTES:

1. THIS DIRECTIVE MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS, I.E., "PROP"
2. YOUNG'S MODULUS MUST BE A POSITIVE NUMBER.
3. POISSON'S RATION MUST SATISFY 0 < NU < 0.5
4. SIGSTAR DEFAULT VALUF IS 1.E10
5. YOU MAY SPECIFY AN INCLUSIVE RANGE OF ELEMENTS TO WHICH THE PROPERTIES WILL BE APPLIED BY ENTERING 'LFIRST' AND 'LLAST' SUCH THAT 0 < 'LFIRST' < 'LLAST'. FOR EXAMPLE, TO SET THE PROPERTIES OF ELEMENTS 2, 3, 4, 5, AND 6, 'LFIRST' = 2 AND 'LLAST' = 6.
   ALTERNATIVELY, YOU MAY SPECIFY THAT THE PROPERTIES ARE TO APPLY TO A LIST OF ELEMENTS. IN THIS CASE, 'LFIRST' = THE LENGTH OF THE LIST, AND 'LLAST' = 0. YOU MUST THEN INCLUDE CARD 2.3 TO LIST THESE ELEMENTS.
6. OMIT THIS CARD IF ALL THE ELEMENTS LFIRST THROUGH LLAST INCLUSIVE ARE TO BE DESCRIBED.

7. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 2.3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

13.4.9 TIES

THE TIES BLOCK PERMITS ENTRY OF CONSTRAINTS BETWEEN NODES. THIS DIFFERS FROM BOUNDARY CONDITIONS IN THAT THE BOUNDARY CONDITIONS SPECIFY CONSTRAINTS BETWEEN NODES AND THE EXTERIOR OF THE STRUCTURE. THE TIES BLOCK ALSO ALLOWS YOU TO JOIN ELEMENTS OF DIFFERENT TYPES.

THE DATA INPUT IN THE TIES BLOCK REQUIRES 'TYING TYPES' DATA BE INPUT IN THE LIBRARY BLOCK.

A SEPARATE TIES BLOCK IS REQUIRED FOR EACH TYING TYPE USED IN THE SUBSTRUCTURE.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1		
	A	SUBSDRC	"TIES"
	CARD 2		
(2)	I	NTYTYP	TYING TYPE NUMBER
	CARD 3		
(3)	I	TIEDNODE	NUMBER OF THIS TIED NODE
	I	RETNODE(1)	FIRST RETAINED NODE
	I	RETNODE(2)	SECOND RETAINED NODE
		.	
		.	
		.	
(4)	I	RETNODE(NRET)	LAST RETAINED NODE

NOTES:

1. THIS CARD SET IS REPEATED UNTIL ALL THE TIES OF A DISTINCT TYING TYPE HAVE BEEN ENTERED. THE TYING TYPES AVAILABLE ARE AS FOLLOWS

   A TYING TYPE 'N' WHICH IS LESS THAN THE MAXIMUM NUMBER OF DEGREES OF FREEDOM 'NDOF' IN THE ANALYSIS CONSTRAINS DEGREE OF FREEDOM 'N' AT THE TIED NODE TO BE EQUAL TO THE DISPLACEMENT OF D.O.F. 'N' OF THE RETAINED NODE.

   A TYING TYPE 'N' WHICH IS GREATER THAN 'NDOF' AND NOT EQUAL TO ANY OF THE SPECIAL TYPES AVAILABLE BELOW CONSTRAINS ALL D.O.F.S AT THE TIED NODE TO ALL THE D.O.F.S AT THE RETAINED NODE.

   A TYING TYPE < 0 INDICATES THAT THE USER HAS ESTABLISHED A SPECIAL TYING TYPE. THE PROGRAM WILL AUTOMATICALLY CALL THE SPECIAL SUBROUTINE 'UFORMS' TO PERFORM THE TYING CALCULATIONS.

   TYPE 18 JOINS TOGETHER BOUNDARIES OF INTERSECTING SHELL ELEMENTS (8 & 20) WHICH LIE ON DIFFERENT SURFACES. AN EXAMPLE OF THIS WOULD BE A SPHERE-CYLINDER JUNCTION. THE TIED NODE MUST ALSO BE ENTERED AS A RETAINED NODE. THIS IS A FULL MOMENT CARRYING JOINT.

   TYPE 19 JOINS A NODE OF BEAM ELEMENT 13 TO A NODE OF A DOUBLY CURVED SHELL ELEMENT (ELEMENT TYPES 8 & 20). TWO RETAINED NODES ARE REQUIRED, BOTH OF WHICH ARE SHELL NODES AND WHICH LIE ALONG ONE OF THE CURVATURE DIRECTIONS OF THE SHELL.

   TYPE 23 JOINS AN AXISYMMETRIC SOLID ELEMENT TO AN AXISYMMETRIC SHELL ELEMENT (ELEMENT TYPE 1). BOTH TIED AND RETAINED NODES MUST BE TRANSFORMED TO LOCAL COORDINATES.

TYPE 28 IS SIMILAR TO TYPE 18, BUT IS A PINNED CONNECTION, RATHER THAN MOMENT CARRYING.

TYPE 701 TIES A NODE OF A LINEAR BRICK (TYPE 7) TO THE FACE OF ANOTHER LINEAR BRICK. THE RETAINED NODES ARE THE 4 CORNER NODES OF THE BRICK FACE TO WHICH THE NODE IS TIED.

2. DATA IN THE TIES BLOCK IS PHYSICALLY FAR REMOVED FROM THE LIBRARY BLOCK (WHICH CONTAINS THE TYING TYPE DATA),IT IS EASIER TO MAKE A MISTAKE HERE THAN ELSEWHERE. PLEASE CHECK THAT THE LIBRARY BLOCK HAS BEEN USED TO SELECT THE PROPER TYING TYPES!

3. CARD 3 IS REPEATED AS OFTEN AS NECESSARY TO ENTER ALL THE TIES OF THIS PARTICULAR TYPE. NOTE THAT IN SOME TYING TYPES, SOME TIED NODES MUST ALSO BE ENTERED IN THE RETAINED LIST.

4. NRET IS THE NUMBER OF RETAINED NODES AS ENTERED IN THE LIBRARY BLOCK 'TYING TYPES'. IF THE LIST LENGTH IS GREATER THAN 16, CONTINUE THE LISTING ON ADDITIONAL CARD 3'S IMMEDIATELY FOLLOWING, UNTIL THE LIST IS SATISFIED. THE MAXIMUM LIST LENGTH PERMITTED IS 128.

13.5 INTERSUBSTRUCTURE CONNECTIVITY

EACH SUBSTRUCTURE MAY BE THOUGHT OF AS A LARGE OR SUPER ELEMENT. EACH OF THESE SUPER ELEMENTS MUST BE CONNECTED TO THE APPROPRIATE NODES OF THE OTHER SUPER ELEMENTS IN THE ANALYSIS. THIS FUNCTION IS PERFORMED THRU THE INTERSUBSTRUCTURE CONNECTIVITY ARRAY, HEREAFTER REFERRED TO AS THE 'ISC' ARRAY.

THIS ARRAY IS ORGANIZED WITH COLUMNS NUMBERED FOR THE SUBSTRUCTURES AND THE ROWS NUMBERED FOR EACH CONNECTION.

THE ISC ARRAY IS REQUIRED INPUT.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
	A	MAINDRC	"INTERSUBSTRUCTURE CONNECTIVITY"
	CARD 2		
	A	ISCDPC	"READ"
	CARD 3		
	I	NROWS	NUMBER OF ROWS IN THE 'ISC' ARRAY

'WABS' INPUT
INTERSUBSTRUCTURE CONNECTIVITY ('ISC')

(1)	CARD 4.1		
(2)	I	ISS	NUMBER OF THE SUBSTRUCTURE. THIS IS IDENTICAL TO THE COLUMN NUMBER OF THE ARRAY.
	I	IROWS	NUMBER OF ROWS TO BE READ FROM CARD 4.2
	I	IFIRST	'ISC' ARRAY ROW NUMBER INTO WHICH THE FIRST TERM APPEARING ON CARD 4.2 IS TO BE ENTERED
	CARD 4.2		
(3)	I	ISC(IFIRST,ISS)	EDGE NODE NUMBER, OR ZERO
		.	
		.	
		.	
(3)	I	ISC(IFIRST+15,ISS)	EDGE NODE NUMBER, OR ZERO
(4)	CARD 5		
	A	ISCDRC	"END"

NOTES:

1. CARDS 4.1 AND 4.2 ARE REPEATED AS A SET UNTIL THE ENTIRE 'ISC' ARRAY HAS BEEN READ. IF, ON CARD 4.1, 'IROWS' > 16, THEN CARD 4.2 WILL EXTEND TO MORE THAN ONE CARD. NOTE THAT LONG STRINGS OF ZEROES MAY BE AVOIDED BY SPECIFYING

CARDS 4.1 AND 4.2 TO READ IN ONLY NONZERO 'ISC' TERMS. IN FACT, TAKEN TO THE LIMIT, ONE COULD READ IN A SET OF CARDS FOR EACH NONZERO TERM IN THE 'ISC' ARRAY.

2. 'ISS' IS THE NUMBER OF THE SUBSTRUCTURE. THUS, THE ENTRY OF THE DATA MAY BE DONE IN ANY ORDER; IT NEED NOT BE ENTERED IN NUMERICAL ORDER. NUMERICAL ORDER IS RECOMMENDED, HOWEVER, BECAUSE IT HELPS YOU KEEP TRACK OF YOUR INPUT.

3. THE TOTAL NUMBER OF 'ISC' ENTRIES MUST BE 'IROWS' FROM CARD 4.1. THUS, IF 'IROWS' > 16, CARD 4.2 MUST BE REPEATED, A MAXIMUM OF 16 'ISC' ENTRIES PER CARD, UNTIL 'IROWS' IS SATISFIED.

4. OPTIONAL CARD. RECOMMENDED FOR NEATNESS.

13.6 ANALYSIS DIRECTIVES

THE ANALYSIS DIRECTIVES DESCRIBE THE PROBLEM AND ANALYSIS PROCEDURES TO SUBSTRC. THIS IS AN OPTIONAL BLOCK. ANY OR ALL OF THE DIRECTIVES IN THIS BLOCK MAY BE COMBINED IN ANY ANALYSIS.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1		
	A	MAINDRC	"ANALYSIS DIRECTIVES"
(2)	CARD 2.1		
(3)	A	ANALDRC	"ALL POINTS"
(4)	CARD 2.2		
(5)	A	ANALDRC	"CENTER POINTS"
(6)	CARD 2.3		
(7)	A	ANALDRC	"ISOTROPIC HARDENING"

CARD 2.4

(8) A ANALDRC "KINEMATI HARDENING"

CARD 2.5

(9) A ANALDRC "LARGE DISPLACEMENT"

(10) CARD 2.6

(11) A ANALDRC "SMALL DISPLACEMENT"

NOTES:

1. ANY OF THE ANALYSIS DIRECTIVES MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS.

2. ANY CARD OF THIS BLOCK MAY BE SELECTED FOR AN ANALYIS. SOME DIRECTIVES CANCEL THE EFFECTS OF OTHERS.

3. THIS DIRECTIVE SELECTS EVALUATION AND PRINTING OF STRESSES AT ALL OF THE ELEMENT INTEGRATION POINTS. THIS OPTION IS ALSO AUTOMATICALLY SELECTED BY THE "LARGE DISPLACEMENT" OPTION. IT IS TO BE USED FOR NONLINEAR ANALYIS, AND WHEN A MORE COMPLETE PICTURE OF THE ELEMENT STRESS DISTRIBUTION IS DESIRED.

4. THIS IS THE PROGRAM DEFAULT. THIS DIRECTIVE CANCELS "ALL POINTS". THIS DIRECTIVE SELECTS EVALUATION AND PRINTING OF STRESSES AT A SINGLE INTEGRATION POINT IN EACH ELEMENT. THE POINT USED IS THE FIRST INTEGRATION POINT OF THE ELEMENT, WHICH USUALLY LIES AT THE CENTROID OF THE ELEMENT, BUT WHICH VARIES DEPENDING ON THE ELEMENT. PLEASE CHECK THE ELEMENT DESCRIPTIONS FOR THE LOCATIONS OF THE ELEMENT INTEGRATION POINTS.

5. THIS IS THE PROGRAM DEFAULT. THIS DIRECTIVE CANCELS "KINEMATIC HARDENING". THIS DIRECTIVE SELECTS ISOTROPIC HARDENING AS THE RULE FOR NON-LINEAR MATERIAL BEHAVIOR.

6. THIS DIRECTIVE CANCELS "ISOTROPIC HARDENING". THIS DIRECTIVE THIS DIRECTIVE SELECTS KINEMATIC HARDENING AS THE RULE FOR NON-LINEAR MATERIAL BEHAVIOR.

7. THIS DIRECTIVE CANCELS "SMALL DISPLACEMENT". THIS DIRECTIVE SELECTS THE USE OF HIGHER ORDER TERMS IN THE FINITE ELEMENT APPROXIMATION TO THE DISPLACEMENT FUNCTION. IT SHOULD BE USED FOR NON-LINEAR ANALYSIS.

8. THIS IS THE PROGRAM DEFAULT. THIS DIRECTIVE CANCELS "LARGE DISPLACEMENT". THIS DIRECTIVE SELECTS ONLY THE FIRST ORDER APPROXIMATION TO THE FINITE ELEMENT DISPLACEMENT FUNCTION.

13.7 BEAM CROSS SECTION DEFINITIONS

THIS OPTIONAL BLOCK PERMITS THE INPUT OF ELEMENT 13 (OPEN SECTION BEAM ELEMENT) CROSS SECTION PROPERTIES.

NOTES	DATA TYPE	VARIABLE	
	CARD 1		
(1)	A	MAINDRC	"BEAM CROSS SECTIONS"
(2)	CARD 2.1		
(3)	I	BEAMNBR	NUMBER OF THE BEAM CROSS SECTION
(4)	A	CARD	LABELING OF THIS CROSS SECTION
	CARD 2.2		
(5)	I	NBRANCH	NUMBER OF BRANCHES TO DEFINE THE CROSS SECTION.
	I	NDIV(1)	THE (EVEN) NUMBER OF DIVISIONS IN THE FIRST BRANCH.
	I	NDIV(2)	THE (EVEN) NUMBER OF DIVISIONS IN THE SECOND BRANCH.
		.	
		.	
		.	

'WABS' INPUT
BEAM CROSS SECTION DEFINITIONS

	I	NDIV(NBRANCH)	THE (EVEN) NUMBER OF DIVISIONS IN THE LAST BRANCH.

CARD 2.3

(6)	R	X1	THE CROSS SECTION X COORDINATE AT THE BEGINNING OF THE BRANCH.
(6)	R	Y1	THE CROSS SECTION Y COORDINATE AT THE BEGINNING OF THE BRANCH.
	R	DX1	DERIVATIVE OF X WITH RESPECT TO S (ARC LENGTH) AT THE BEGINNING OF THE BRANCH.
	R	DY1	DERIVATIVE OF Y WITH RESPECT TO S AT THE BEGINNING OF THE BRANCH.
	R	X2	THE CROSS SECTION X COORDINATE AT THE END OF THE BRANCH.
	R	Y2	THE CROSS SECTION Y COORDINATE AT THE END OF THE BRANCH.
	R	DX2	DERIVATIVE OF X WITH RESPECT TO S AT END OF THE BRANCH.
	R	DY2	DERIVATIVE OF Y WITH RESPECT TO S AT END OF THE BRANCH.

CARD 2.4

	R	BRLONG	LENGTH OF THE BRANCH.
	R	T1	THICKNESS OF THE BRANCH AT THE BEGINNING OF THE BRANCH.
(7)	R	T2	THICKNESS AT THE END OF THE BRANCH.

(8) CARD 3

A	MAINDRC	"END"

NOTES:

1. ALL OF THE DIRECTIVES MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS.

2. CARD SET 2 IS REPEATED UNTIL ALL THE BEAM CROSS SECTION DESCRIPTIONS HAVE BEEN ENTERED.

3. BEAM CROSS SECTIONS ARE ASSOCIATED WITH A UNIQUE USER-DEFINED CROSS SECTION IDENTIFIER 'BEAMNBR'. 'BEAMNBR' IS REFERRED TO THROUGH PARAMETER 'EGEOM2' OF THE "GEOMETRY" BLOCK IN THE APPROPRIATE SUBSTRUCTURES. THESE MUST BE NUMBERED CONSECUTIVELY (NO OMISSIONS!) AND INPUT IN NUMERICAL ORDER.

4. THE LABEL HERE IS PRIMARILY FOR YOUR OWN REFERENCE, AS SUBSTRC MERELY READS THIS AND PRINTS IT. IT SHOULD BE INFORMATION WHICH WILL HELP YOU REMEMBER WHAT YOU ARE DOING IN THIS ANALYSIS.

5. 'NBRANCH' CONTROLS THE NUMBER OF CARDS 2.3 AND 2.4 TO BE READ IN THIS CROSS SECTION DESCRIPTION. THE MAXIMUM VALUE 'NBRANCH' MAY

ASSUME IS 15. NOTE THAT THE TOTAL NUMBER OF DIVISIONS (THE SUM OF NDIV(1) THRU NDIV('NBRANCH') MUST BE EVEN, AND LESS THAN OR EQUAL TO 30.

6. X1 AND Y1 NEED BE SPECIFIED ONLY ONCE (ON THE FIRST CARD 2.3), AS EACH SUCCESIVE BRANCH MUST START FROM THE END OF THE PREVIOUS BRANCH. SUCCESSIVE CARD 2.3'S CONTAIN ONLY THE 6 ENTRIES: DX1, DY1, X2, Y2, DX2, DY2.

7. T2 DEFAULTS TO T1 IF IT IS LEFT BLANK.

8. OPTIONAL CARD. RECOMMENDED FOR NEATNESS.

13.8 LOADING HISTORY

THESE OPTIONAL DATA CONTROL THE APPLICATION OF LOAD TO THE MATHEMATICAL MODEL AFTER THE INITIAL LOADING.

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1		
	A	MAINDRC	"LOADING HISTORY"
(2)	CARD 2.1		
	A	LOADDRC	"PROPORTIONAL INCREMENT"
	CARD 2.2		
(3)	R	FACTO	MULTIPLIER OF THE PREVIOUS LOAD INCREMENT

NOTES:

1. ALL OF THE DIRECTIVES MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS.
2. THIS CARD SET IS REPEATED AS OFTEN AS NECESSARY TO COMPLETELY DEFINE THE LOADING HISTORY OF THE PROBLEM.
3. SAY THE DESIRED LOADING SCHEDULE IS 1000, 2000, 2100, 2125. THE INPUT DATA TO PRODUCE THIS LOADING HISTORY REQUIRES THAT THE INITIAL LOAD BE APPLIED IN THE APPROPRIATE SUBSTRUCTURES THRU THE USE OF EITHER DISTRIBUTED OR CONCENTRATED LOADS, AND THE FOLLOWING INPUT BE PROVIDED IN THE LOADING HISTORY BLOCK:

'WABS' INPUT
LOADING HISTORY

```
PROP
1.0
PROP
0.1
PROP
0.25
```

LETTING 'LOAD I' INDICATE THE LOAD VALUE AT STEP I AND 'DELLOAD I' AS THE LOAD INCREMENT FROM 'LOAD I' TO 'LOAD I+1', WE SHOW THAT THE PROGRAM USES VALUES OF 'FACTO' TO INCREASE THE LOAD LEVELS AS FOLLOWS:

```
LOAD1    = DELLOAD1 = 1000

LOAD2    = LOAD1 + ( FACTO*DELLOAD1 )
         = 1000  + (    1.0*1000    )
         = 2000

DELLOAD2 = FACTO * DELLOAD1 = .1 * 1000  = 100
LOAD3    = LOAD2 + DELLOAD2 = 2000 + 100 = 2100

DELLOAD3 = FACTO * DELLOAD2 = .25 * 100 = 25
LOAD4    = LOAD3 + DELLOAD3 = 2100 + 25 = 2125
```

13.9 SOLUTION DIRECTIVES

THIS BLOCK OF INFORMATION ALLOWS YOU TO DIRECT THE SOLUTION OF THE PROBLEM. THIS IS AN OPTIONAL BLOCK; FOR A "SMALL" ANALYSIS (ONE IN WHICH THE ENTIRE PROBLEM CAN BE RUN AT ONE TIME), THIS BLOCK MAY NOT NECESSARY.

THE FOLLOWING IS A LIST OF THE AVAILABLE DIRECTIVES IN THE SOLUTION DIRECTIVES BLOCK.

GO (DEFAULT)
NOGO
GOERRORS
DECOMPOSITION
EDGE NODES
RELAXATION
RESTART

NOTES	DATA TYPE	VARIABLE	
(1)	CARD 1		
	A	MAINDRC	"SOLUTION DIRECTIVES"
	CARD 2		
(2)	A	SOLUDRC	"GO"

'WABS' INPUT
SOLUTION DIRECTIVES

```
        CARD  3
(3)     A    SOLUDRC                  "NOGO"

        CARD  4
(4)     A    SOLUDRC                  "GOERRORS"

(5)     CARD  5.1
(6)     A    SOLUDRC                  "DECOMPOSE"

(7)     CARD  5.2
        A    SOLUDRC                  "EDGE NODES"

(8)     CARD  5.3
        A    SOLUDRC                  "RELAXATION"

(9)     CARD  6
        A    SOLUDRC                  "RESTART"
```

NOTES:

1. ALL OF THE SOLUTION DIRECTIVES MAY BE ABBREVIATED TO THE FIRST 4 CHARACTERS.
2. EXECUTE THE ANALYSIS.
3. STOP AFTER CHECKING THE DATA - THIS OPTION IS

PRIMARILY USED IN UPDATING AND MODIFYING THE PROGRAM, AND IN CHECKING THE DATA.

4. PERMITS SOLUTION TO CONTINUE EVEN THOUGH THERE ARE INPUT ERRORS. EXERCISE CAUTION WHEN USING THIS OPTION.

5. SELECTION OF ANY CARD IN CARD SET 5 EXCLUDES THE USE OF ANY OTHER CARD IN SET 5. CARD SET 5 AND CARD 6 ARE ALSO MUTUALLY EXCLUSIVE.

6. THIS DIRECTIVE SIGNALS THAT A SUBSTRUCTURE STIFFNESS MATRIX IS TO BE DECOMPOSED WITH ALL THE EDGE NODES CONSTRAINED (COMPLETELY FIXED).

7. ANALYZE THE STIFFNESS OF THE EDGE NODES ONLY.

8. RELAX THE CONSTRAINTS OF COMPLETE FIXITY ON THE SUBSTRUCTURE BORDERS, BACK SUBSTITUTE, AND PRINT ALL THE REQUIRED OUTPUT.

9. RESTART A NONLINEAR ANALYSIS FROM A PREVIOUS CONDITION. USE OF THIS OPTION IS MUTUALLY EXCLUSIVE WITH ANY OPTION IN CARD SET 5.

CHAPTER 14

A NONLINEAR EXAMPLE

14.1 INTRODUCTION

NOTE: 1 in. = 2.54 cm
1 psi = 6.895×10^3 Pa
1 pound = 0.453 kg

Preparing data for a nonlinear analysis is similar to doing it for a "one shot" linear analysis. All of the tools for data generation are applicable. If plasticity is anticipated, additional work involves input of a uniaxial material curve. The most difficult task is specifying load increments and picking a tolerance ratio for resulting incremental displacements. Until the user has sufficient experience with a class of problems, it will be necessary to input different tolerances and different load step sizes to determine the solution's sensitivity to such variations.

A general word of caution is appropriate here. A grid work that produces perfectly good linear results may not be fine enough to model the nonlinear behavior of a structure. This is because the linear solution might have displacements that vary gradually with respect to position on the surface. A relatively coarse grid pattern could adequately model such behavior. The nonlinear solution, however, might have displacements that vary rapidly with respect to position on the surface. A finer grid must model this. An example of such a situation is a pressure loaded, axisymmetric cylinder. In a linear analysis the radial displacement would not vary going around the circumference; whereas for a nonlinear analysis a multiwave displacement pattern could develop, requiring more elements in the circumferential direction.

14.2 MATHEMATICAL MODEL

14.2.1 Physical Data

We choose to model a circular ring of radius 20.0 in., width 2.6 in. and thickness 0.4 in. Young's Modulus and Poisson's ratio were taken as 3E07 psi and 0.3 respectively. This particular model was treated earlier in {JONES77} using the triangular shell element 8. Here the 2-dimensional beam element 16 is used.

The ring is known to deform elastically in two waves around the circumference. The buckling pressure P is given by:

$$P = 3EI/R^3$$

where E, I, and R are Young's Modulus, cross section moment of inertia, and the centroidal radius, respectively. For this model P = 60 psi. For the material non-linearity a hypothetical work hardening curve was used that takes effect at a proportional limit stress of 2400 psi. The material curve is shown in Figure 14.1.

14.2.2 Modeling Considerations

A sketch of the model is shown in Figure 14.2. The anticipated buckling pattern allowed the modeling of only 90 deg of the ring. Symmetry boundary conditions were imposed on the nodes at 0 and 90 deg. Element type 16 has four degrees of freedom per node. The boundary conditions imposed were one displacement and one rotation set equal to zero at each of the ends.

The model was divided into two substructures of 45 deg, each containing three elements.

Two methods have been successfully employed to perturb an axisymmetric model out of an axisymmetric deflection pattern: kicker loads and imperfect geometry. The first method, which was used in this example, is to apply a small, concentrated radial load at one point. The load used here was 0.340E-05 pounds applied in the negative Y direction to node one of substructure one. At the same time a small initial pressure load of 0.10E-02 psi was applied to the whole structure. Note that both loads are increased when the Proportional Increment option is used. The program applies the initial loads linearly. For all subsequent load steps higher order terms are included in the displacement equations. For this reason the initial loading is always small, to "turn on" the nonlinear analysis as soon as possible.

The second method of perturbation involves making slight changes to the coordinates of the "perfect" model. If all possible mode shapes are included in the coordinate perturbation, the model will not be artificially forced into a particular

mode. It was reported in {JONES77} that imposing a four wave mode shape on this model prevented the model from buckling in the critical two wave modes and forced it into the four wave modes with a pressure of 300 psi.

14.3 INPUT TO "SUBSTRC"

The extreme simplicity of this model made it possible to generate all of the data manually.

14.4 CASES RUN

In a nonlinear analysis, at each load step incremental displacements are estimated prior to an analysis and calculated at the end of the analysis. The user must specify for a particular monitored degree of freedom how close those two displacements must be, using the input tolerance ratio FRCTOL. For example, a FRCTOL of 1.05 corresponds to a tolerance of five percent. The tolerance ratio is discussed in {JONES73} and {JONES77}. It should be kept in mind that FRCTOL is applied to incremental displacement not to total displacement. It is an imprecise measure of accuracy because it compares current incremental displacement only with the previous estimate, not with the "actual" value. Thus a chosen FRCTOL of 1.05, for example, does not mean that incremental displacements are guaranteed to be within five percent of the "actual" value (where the "actual" value could be defined as the value achieved with FRCTOL of 1.0). It only means that tolerance will be considered satisfied when the incremental displacement for the n^{th} iteration is within five percent of that calculated for the $(n-1)^{th}$ iteration.

Data for this model was run a total of four times. For the first two runs the proportional limit stress was set high to keep the analysis elastic. For the first run the tolerance ratio for the monitored displacement, FRCTOL, was set to 1.2. For the second run it was tightened to 1.01 to see how sensitive the results were. Figure 14.3 shows a plot of monitored displacement, radial under the perturbing load, versus applied pressure. As the displacements became more nonlinear, the difference in displacements for the two cases became more pronounced. However, in both cases there was a sharp change in slope between 56 and 59.5 psi indicating approaching

buckling. Thus if a predicted buckling pressure was the result sought, the looser tolerance was acceptable. It should be noted that for a buckling analysis, unless the user has previous experience with a particular type of structure, he shouldn't be satisfied with a single run.

Cases 3 and 4 were run with a proportional limit stress of 2400 psi. The work hardening option was selected for the material curve in Figure 14.1. The looser displacement tolerance of 1.2 was used because it seemed satisfactory for the elastic case. The only difference between cases 3 and 4 was that the load increments were half as large for case 4. Points plotted in Figure 14.3 represent load steps. Plasticity was reached in the load step from 45.5 psi to 49 psi. For a ring every element becomes plastic at the same time. There is no way to redistribute the load to lower stressed areas and the ring here consequently buckled at about 51 psi.

Note that the step sizes are considerably smaller for the two plastic cases than for the elastic cases. In general this is necessary because of the path dependency of the plastic behavior of materials. The user will have to determine the sensitivity of his model to load step size.

The cost of running case three at current rates, using priority two, was $17.10. This was for nine successful load steps and a total of twenty iterations.

14.5 MISCELLANEOUS OBSERVATIONS

Experience with this and other models has led to several observations that may save the user time and expense:

1. It is advantageous to have some a priori knowledge of the buckling shape of the model. This allows modeling a fraction of the structure and applying symmetry boundary conditions to one or more edges. It also helps the user to decide the number and distribution of elements required to accurately model the anticipated shape. For example, if an axisymmetric cylinder is expected to buckle in two circumferential waves, only a ninety degree segment must be modeled. Symmetry boundary conditions are then applied along the zero and ninety degree generators. The number of elements required in the ninety degree segment would of course depend on the element type used. It appears that for element type 20, six elements give the proper buckling load while three elements will give a buckling load about five percent higher.

A NONLINEAR EXAMPLE

2. During a nonlinear analysis the program currently monitors the displacement at a degree of freedom specified by the user, always in the first substructure. During the early loading, when the response is essentially linear, the monitored node will displace in one direction. However, when the model starts to assume a buckled shape, that node may very well start to displace in the opposite direction.

For example, initially a uniform ring will displace radially inward at all points when subjected to pressure loading. As a two wave buckling pattern starts to form, the incremental displacements for some points will continue to be radial inward but other points will start to move outward. If one of these latter points is being monitored, the convergence will be relatively slow at the load step where the incremental displacement changes sign. Therefore, to avoid needless iterations, if possible choose to monitor a degree of freedom whose displacement does not change sign as a buckling pattern develops.

3. It appears, from experience to data, that the nonlinear buckling analysis of cylindrical shells requires the perturbing influence of either small point loads or small coordinate modifications. It was initially supposed that the nonaxisymmetric deflection induced in the shell by attached nonaxisymmetric internal structure would be enough to produce nonlinearity, and then buckling, but such was not the case. It was not until the shell coordinates were perturbed that the expected response was produced.

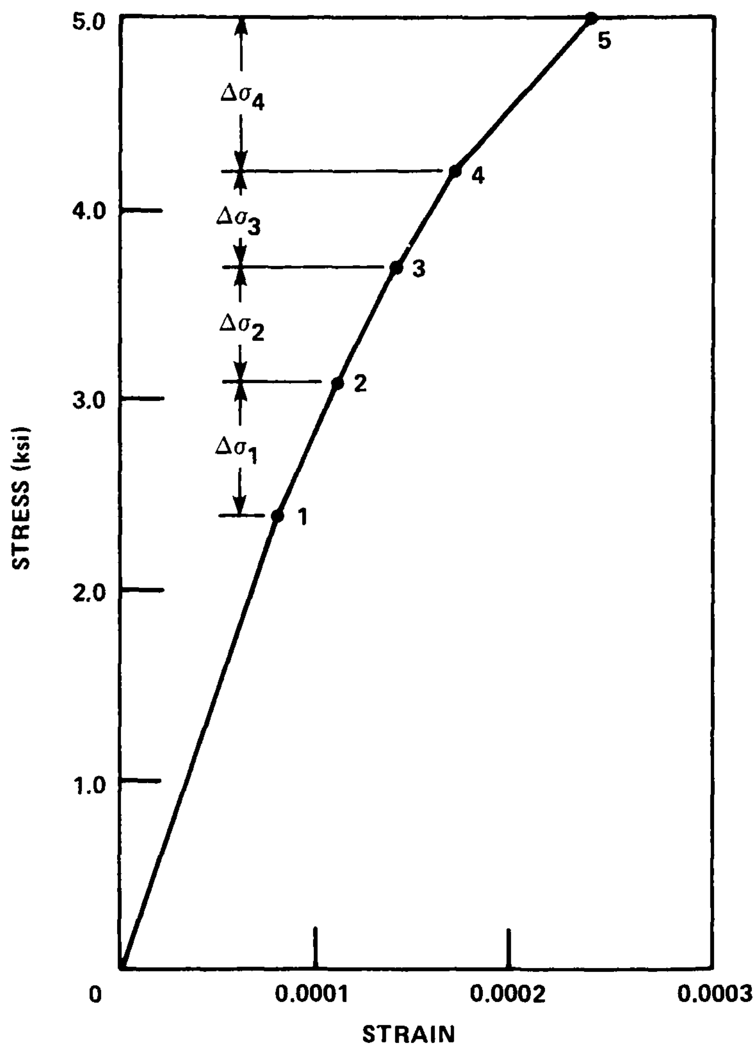

Figure 14.1 - Material Curve for Nonlinear Example

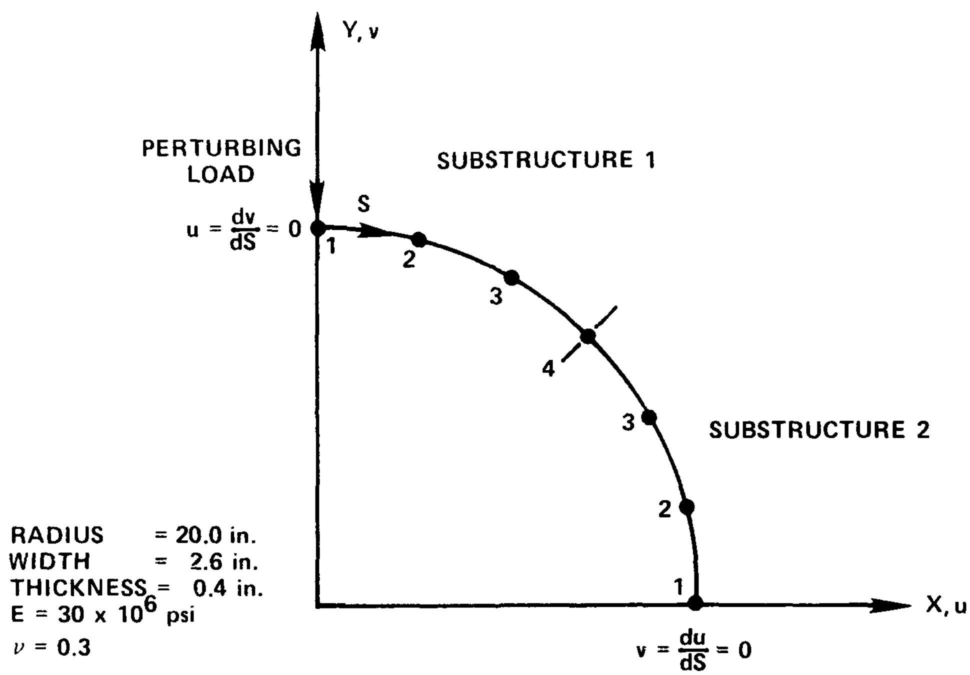

Figure 14.2 - Model for Nonlinear Example

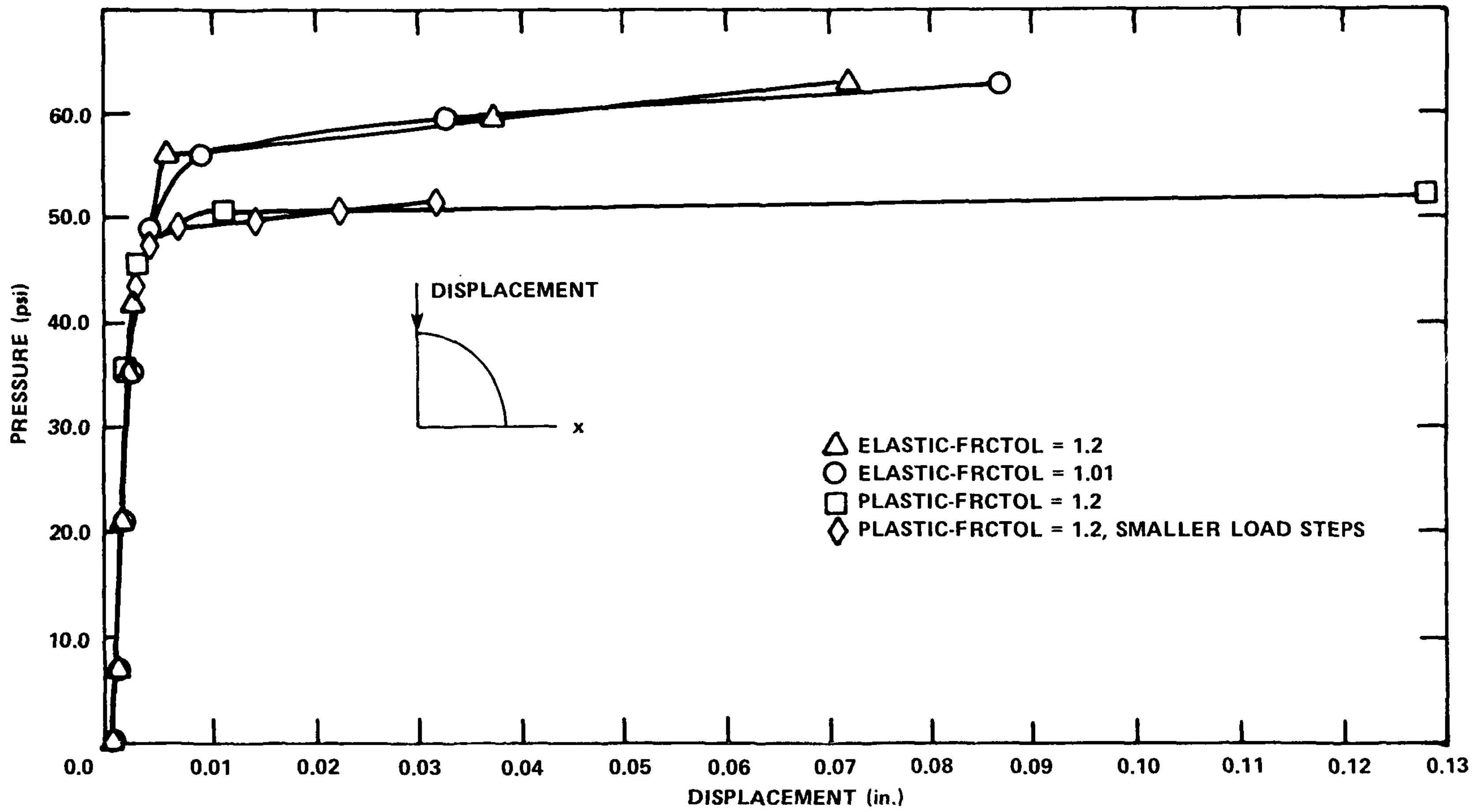

Figure 14.3 - Displacements for Nonlinear Example

CHAPTER 15

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